Materials & Processes Laboratory Report
Huntington Beach Site Host Engineering

Lab Report No. 2'nd Draft	**Date: June 11, 2007**
Requested by: Eric Eichinger and Matthew Rothgeb	**Responsible Engineer: John Patterson**
TITLE: DISSIMILAR METALS CORROSION TESTING OF NON-CHROME COATING SYSTEMS	

Prepared by:

J. D. Patterson, Engineer/Scientist
Chemistry
Non-Metallics, BCA Support & Chemistry
Materials & Processes
HB Site Host Engineering

Approved by:

C. E. David, Manager
Chemistry
Non-Metallics, BCA Support & Chemistry
Materials & Processes
HB Site Host Engineering

R. J. Menke, Manager
Non-Metallics/Contamination Control
Non-Metallics, BCA Support & Chemistry
Materials & Processes
HB Site Host Engineering

TITLE: **DISSIMILAR METALS CORROSION TESTING OF NON-CHROME COATING SYSTEMS**

DISTRIBUTION: Eric Eichinger; Matt Rothgeb; Carey David; Richard Menke; Ravijit Kahandal; Richard Snell; Thomas Collins; George Frey; Joe Robinson; MaryAnn Forrest-Woodward; Wayne Elsaesser; Terrell Riley; Robert Mullen; Jeremy Jacobs; Richard Russell; Erica Sullivan; Sree Chakravarthy; Cris Curtis; Catherine Kammerer; Mark Kolody; Marcella Solomon; Kenneth Wagner; William Wendorff

SUMMARY:
Five non-chrome coating systems were evaluated in this study for dissimilar metals corrosion resistance. This effort was in support of a NASA Technology Evaluation for Environmental Risk Mitigation (TEERM) program which included two chromated systems as controls. Non-chrome coating systems in this study did not provide equivalent corrosion protection as the chromated controls on aluminum substrate. This finding suggests that further development of non-chrome coating technology is necessary to serve as a permanent corrosion barrier of interior aircraft structure where access and inspection may be limited.

Two non-chrome coating systems outperformed the others on faying surfaces in this study. They were System N (Pantheon Pre-Kote with Akzo Mg-Rich Primer) and System T (Henkel Alodine 5700 with Akzo Sicopoxy 577-630 Primer). System N experienced a blistering problem in direct salt fog, which may indicate it requires a polyurethane topcoat. Further testing is recommended to investigate possible synergistic effects between surface treatments and primers to identify a non-chrome coating system capable of widespread use in aerospace applications.

INTRODUCTION:

Within NASA, the Technology Evaluation for Environmental Risk Mitigation (TEERM) Principal Center has the responsibility for helping NASA Centers and programs identify and test environmentally preferable and sustainable technologies. TEERM coordinated this test effort with various NASA and DOD partners to perform a wide variety of tests on the latest generation of non-chrome paint system for aerospace applications. A dissimilar metals corrosion test was performed at the Boeing Huntington Beach Laboratories in support of this NASA TEERM project, which is the focus of this report.

The dissimilar metals corrosion test simultaneously provides two exposure environments for evaluation. Direct salt fog exposure occurs on the outer primed aluminum surfaces while salt water migration occurs into the crevices of the primed faying surfaces. The effects of stagnant fluids within crevices can be quite severe due to the depletion of oxygen, the concentration of ions, and a shift towards acidic conditions during the exposure period. The crevice corrosion potential is intensified by joining galvanically different substrates in test.

Although dissimilar metal joints are generally avoided in aerospace design, there are occasions where galvanically dissimilar metals need to be joined. These locations are prone to accelerated corrosive attack when exposed to moist service environments. The Boeing dissimilar metals corrosion test challenges the corrosion inhibitive properties of a coating system applied between aluminum and titanium alloys in 2000 hours of salt fog exposure. This test method is used to qualify interior primers for structural applications on Douglas Heritage aircraft in DMS 1786.

Interior primers are intended to serve as a permanent coating system for the life of the vehicle. They are also applied in regions with limited access that may receive inspection once for every five years of service life. For these reasons, interior coating system corrosion tests need to be severe. Any chrome-free coating system that can provide adequate performance in the dissimilar metals corrosion test would be of great interest to airframe manufacturers and operators alike.

OBJECTIVE:

Perform the dissimilar metals corrosion testing in support of the NASA TEERM project to evaluate various non-chrome paint systems for consideration in aerospace applications.

MATERIALS:

Surface treatment and primer systems identified in Table 1 were applied to aluminum substrate at Hill Air Force Base to test specimens furnished by Boeing.

TABLE 1: CHROME-FREE COATING SYSTEMS AND CONTROL

Designation	Surface Treatment	Primer
System B	BoeGel EP-II (AC-131-CB) Chrome-Free Sol Gel Coating for All Metal	DuPont Corlar 13570S Chrome-Free, High Solids Epoxy Polyamide
System C Chromated Control 1	Henkel Alodine 1200S Chromated Conversion Coating MIL-C-5541 Ty 1A on Aluminum	Deft 02-Y-40 Chromated MIL-P-23377 Ty I High Solids Epoxy Polyamide
System H	Henkel Alodine 5700 Chrome-Free Conversion Coating For Aluminum	Hentzen Primer 05510WEP-X Chrome-Free MIL-P-53022 Ty I Conventional Polyamide Epoxy
System N	Pantheon PreKote Chrome-Free Surface Pretreatment for All Metal	Akzo Mg-Rich Primer Chrome-Free, Exempt Solvent Epoxy Polyamide
System S	Pantheon PreKote Chrome-Free Surface Pretreatment for All Metal	AquaSur Tech Crosslinker with AquaSur Tech AST-D45-AMS-MO Chrome-Free, High Solids Epoxy Primer and Polyurethane Topcoat
System T	Henkel Alodine 5700 Chrome-Free Conversion Coating For Aluminum	Akzo Sicopoxy 577-630 Chrome-Free, High Solids Epoxy Polyamide

A second chromated control system was prepared at Boeing to baseline an Orbiter vehicle coating system which appears in Table 2.

TABLE 2: ORBITER COATING SYSTEM - CONTROL 2

Designation	Surface Treatment	Primer
System O Chromated Control 2	Henkel Alodine 1200S Chromated Conversion Coating MIL-C-5541 Ty 1A on Aluminum	PPG Aerospace 515K012 Chromated MB0125-055 Conventional Amine-Cured Epoxy

The formulation of Orbiter primer (PPG Aerospace 515K012) differs significantly from the chromated MIL-P-23377 primer (Deft 02-Y-40) material as shown in Table 3. Talc is used in PPG Aerospace 515K012 to aid in water permeation which improves chromate solubility in the coating. These formulation differences justified the inclusion of a secondary control.

TABLE 3: FORMULATION DIFFERENCES BETWEEN CONTROL PRIMERS

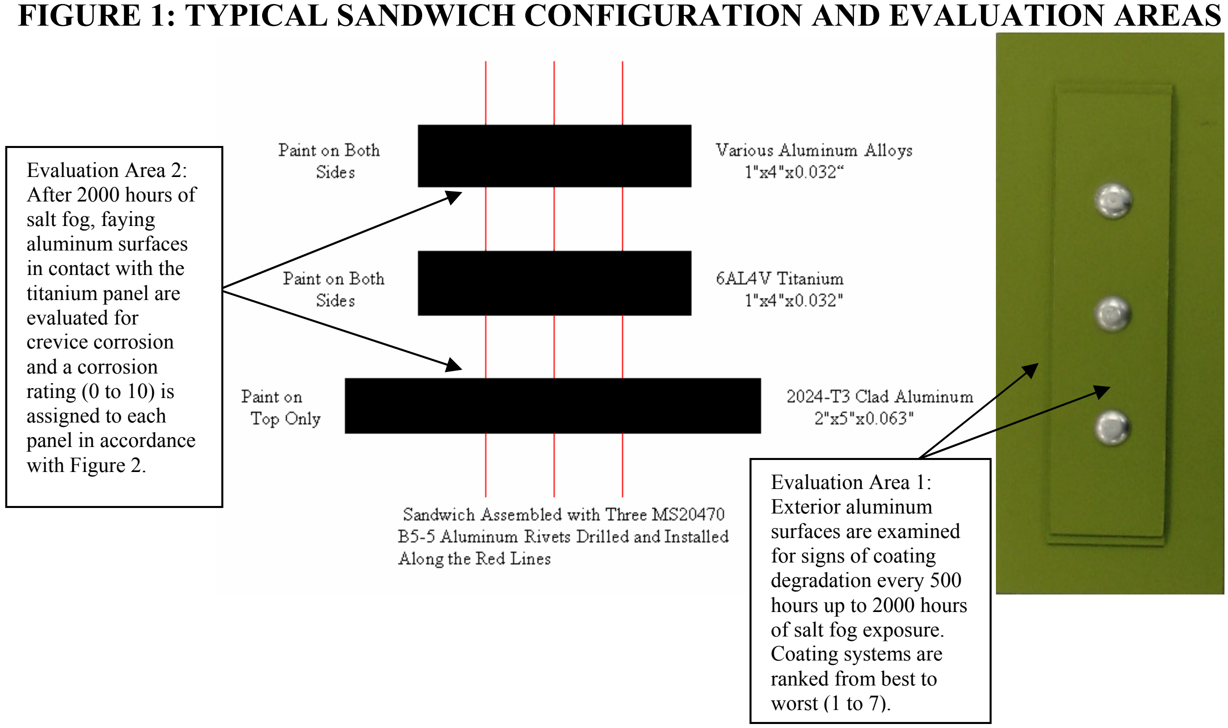
Formulation Differences	Deft 02-Y-40	PPG Aerospace 515K012
Resin System Approximate Weight % in Cured Coating	Polyamide-Cured Epoxy 65%	Amine-Cured Epoxy 40%
Soluble Chromate Type Approximate Weight % in Cured Coating Solubility Product Constant at 77°F	Strontium Chromate 35% $2.2x10^{-5}$	Calcium Chromate 7% $7.1x10^{-4}$
Other Fillers and Pigments Approximate Weight % in Cured Coating	N/A 0%	Talc, 38% TiO_2 & Fe_2O_3, 14%

<u>TEST SPECIMEN DESCRIPTION</u>:
Substrate materials that appear in Table 4 are coated and assembled into the typical dissimilar metals sandwich configuration shown in Figure 1.

TABLE 4: DISIMILAR METALS SANDWICH CONFIGURATIONS

Sandwich Configuration ID (Run in Triplicate For Each Coating System)	Total Quantity Required For Seven Coating Systems in Test
Sandwich Configuration A	
2024-T3 Alclad 2" x 5" x .063" - Prime One Side Only	21
6AL-4V Titanium 1" x 4" x .032" - Prime Both Sides	21
7075-T6 Alclad 1" x 4" x .032" - Prime Both Sides	21
MS20470 B5-5 Aluminum Rivets - Drill and Install Dry	63
Sandwich Configuration B	
2024-T3 Alclad 2" x 5" x .063" - Prime One Side Only	21
6AL-4V Titanium 1" x 4" x .032" - Prime Both Sides	21
7075-T6 Bare 1" x 4" x .032" - Prime Both Sides	21
MS20470 B5-5 Aluminum Rivets - Drill and Install Dry	63
Sandwich Configuration C	
2024-T3 Alclad 2" x 5" x .063" - Prime One Side Only	21
6AL-4V Titanium 1" x 4" x .032" - Prime Both Sides	21
2024-T3 Bare 1" x 4" x .032" - Prime Both Sides	21
MS20470 B5-5 Aluminum Rivets - Drill and Install Dry	63
Sandwich Configuration D	
2024-T3 Alclad 2" x 5" x .063" - Prime One Side Only	21
6AL-4V Titanium 1" x 4" x .032" - Prime Both Sides	21
2024-T3 Clad 1" x 4" x .032" - Prime Both Sides	21
MS20470 B5-5 Aluminum Rivets - Drill and Install Dry	63

FIGURE 1: TYPICAL SANDWICH CONFIGURATION AND EVALUATION AREAS



PROCEDURE:

Coatings identified in Table 1 were applied at Hill Air Force Base in accordance with the manufacturers' instructions on the aluminum substrate specified in Table 4. Coatings identified in Table 2 were applied at Boeing Huntington Beach in accordance with the manufacturers' instructions on aluminum substrate specified in Table 4. All 6AL-4V titanium in this study was passivated, abraded with 400 grit silicon carbide sandpaper, solvent cleaned with methyl propyl ketone, and coated on both sides with the primers identified in Table 1 & 2. This test is a modification of DMS 1786 dissimilar metals corrosion test to accommodate the chrome-free coating systems of interest in this study.

Applied coating systems air dried for 7 days minimum at ambient conditions prior to assembly into the sandwich panel configurations shown in Table 4 and Figure 1. Each coating system had three sets of each sandwich configuration exposed to ASTM B 117 salt fog. At 500-hour intervals, all sandwich panels were removed from salt fog, photographed and examined for exterior signs of blistering and corrosion. Coating systems were ranked from 1 to 7 (best to worst) based upon their exterior appearance at each 500-hour interval.

After 2000 hours of salt fog exposure, rivets were drilled out and the sandwich panels were disassembled and marked with identification codes. Faying aluminum surfaces were rinsed with deionized water, air dried, and 3M Scotch #250 pressure-sensitive tape was applied over the entire faying surface area and immediately removed. Areas with corrosion activity were exposed. Aluminum panels were mounted, photographed, examined, and the rated on a scale of 0 to 10 as shown in Figure 2 for coating failures caused by corrosion.

RESULTS:

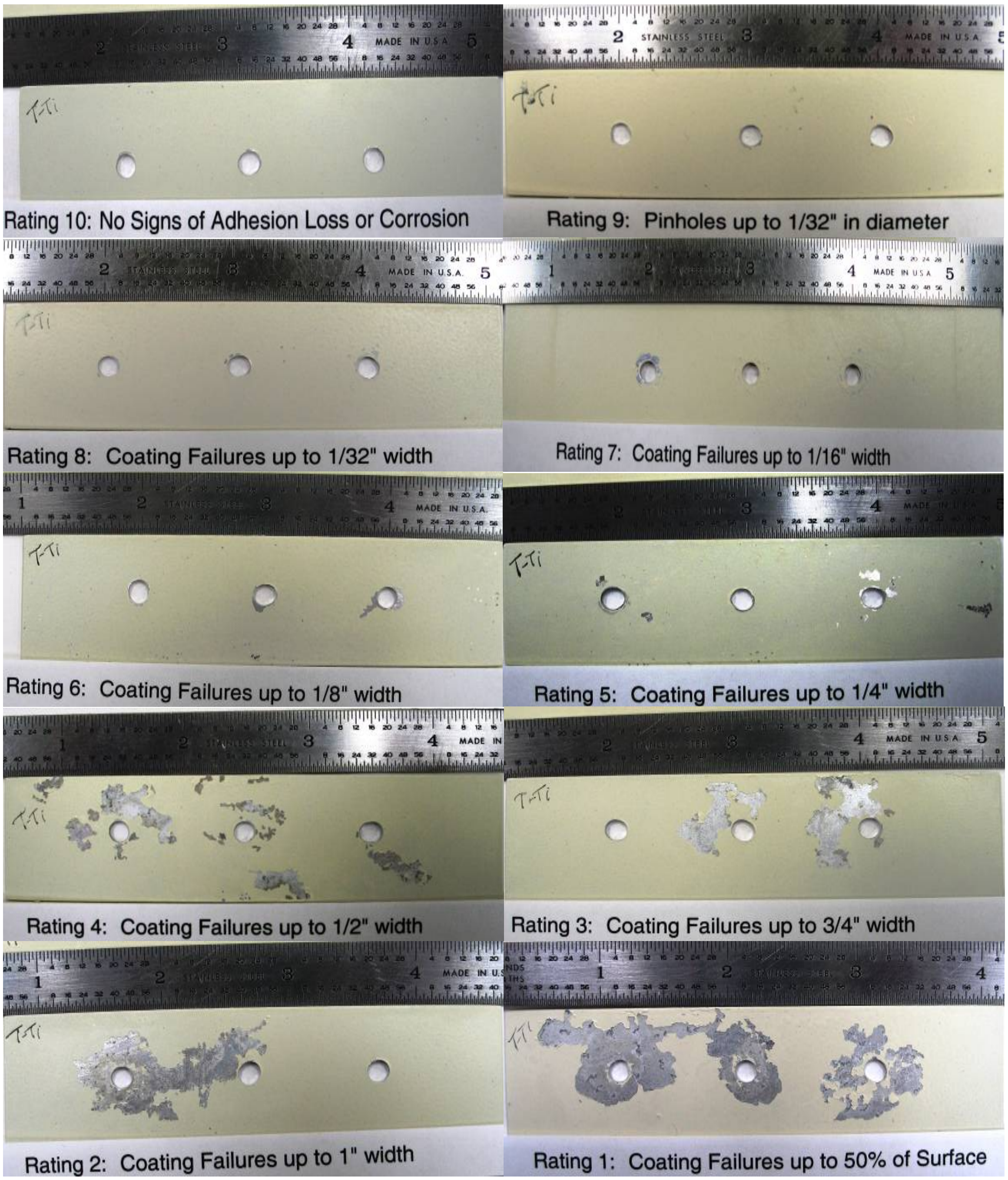
Coating systems were photographed for every 500 hours of salt fog exposure which can be found in this report's attachments section. The exterior appearance of each coating system was ranked relative to each other from 1 to 7 (best to worst) during each 500 hour inspection period. Results from this evaluation of Area 1 as shown in Figure 1 are provided in Table 5.

TABLE 5: COATING SYSTEMS EXTERIOR APPEARANCE RANK DURING SALT FOG EXPOSURE

Designation	500-Hour Exposure	1000-Hour Exposure	1500-Hour Exposure	2000-Hour Exposure
System B	3	3	3	4
System C (Control 1)	2	2	2	1
System H	5	4	4	3
System N	6	6	6	6
System O (Control 2)	1	1	1	2
System S	7	7	7	7
System T	4	5	5	5

After 2000 hours of salt fog exposure, panels were disassembled and the faying aluminum surfaces in direct contact with the titanium (Evaluation Area 2 as shown in Figure 1) were cleaned, tape tested, and mounted for inspection and photographs. Photos are located in this report in the attachment section. Coating loss and corrosion were critiqued based upon the rating system depicted in Figure 2. Coating system performance ratings and averages for each aluminum alloy in test are provided in Table 6 through Table 12.

FIGURE 2: COATING LOSS & CORROSION RATING SYSTEM



Rating 10: No Signs of Adhesion Loss or Corrosion

Rating 9: Pinholes up to 1/32" in diameter

Rating 8: Coating Failures up to 1/32" width

Rating 7: Coating Failures up to 1/16" width

Rating 6: Coating Failures up to 1/8" width

Rating 5: Coating Failures up to 1/4" width

Rating 4: Coating Failures up to 1/2" width

Rating 3: Coating Failures up to 3/4" width

Rating 2: Coating Failures up to 1" width

Rating 1: Coating Failures up to 50% of Surface

Rating of 0: Coating Failure Exceeding 50% of Surface.

TABLE 6: COATING SYSTEM B ALUMINUM CORROSION RATING

Sandwich Configuration Letter	1"x 4" Aluminum Substrate Type	Corrosion Rating on 1"x 4" Aluminum Substrate After 2000-Hour Exposure	Corrosion Rating on 2"x 5" 2024-T3 Alclad Aluminum Substrate After 2000-Hour Exposure
A1	7075-T6 Alclad	2	9
A2	7075-T6 Alclad	3	8
A3	7075-T6 Alclad	2	7
A Ave	7075-T6 Alclad	2.3	8.0
B1	7075-T6 Bare	8	3
B2	7075-T6 Bare	6	5
B3	7075-T6 Bare	7	2
B Ave	7075-T6 Bare	7.0	3.3
C1	2024-T3 Bare	1	8
C2	2024-T3 Bare	1	8
C3	2024-T3 Bare	2	9
C Ave	2024-T3 Bare	1.3	8.3
D1	2024-T3 Alclad	5	8
D2	2024-T3 Alclad	7	7
D3	2024-T3 Alclad	5	8
D Ave	2024-T3 Alclad	5.7	7.7

TABLE 7: COATING SYSTEM C ALUMINUM CORROSION RATING

Sandwich Configuration Letter	1"x 4" Aluminum Substrate Type	Corrosion Rating on 1"x 4" Aluminum Substrate After 2000-Hour Exposure	Corrosion Rating on 2"x 5" 2024-T3 Alclad Aluminum Substrate After 2000-Hour Exposure
A1	7075-T6 Alclad	8	9
A2	7075-T6 Alclad	8	7
A3	7075-T6 Alclad	8	7
A Ave	7075-T6 Alclad	8.0	7.7
B1	7075-T6 Bare	8	7
B2	7075-T6 Bare	8	7
B3	7075-T6 Bare	8	7
B Ave	7075-T6 Bare	8.0	7.0
C1	2024-T3 Bare	6	7
C2	2024-T3 Bare	6	6
C3	2024-T3 Bare	6	9
C Ave	2024-T3 Bare	6.0	7.3
D1	2024-T3 Alclad	8	7
D2	2024-T3 Alclad	8	8
D3	2024-T3 Alclad	9	8
D Ave	2024-T3 Alclad	8.3	7.7

TABLE 8: COATING SYSTEM H ALUMINUM CORROSION RATING

Sandwich Configuration Letter	1"x 4" Aluminum Substrate Type	Corrosion Rating on 1"x 4" Aluminum Substrate After 2000-Hour Exposure	Corrosion Rating on 2"x 5" 2024-T3 Alclad Aluminum Substrate After 2000-Hour Exposure
A1	7075-T6 Alclad	2	7
A2	7075-T6 Alclad	3	6
A3	7075-T6 Alclad	9	2
A Ave	7075-T6 Alclad	4.7	5.0
B1	7075-T6 Bare	5	6
B2	7075-T6 Bare	2	7
B3	7075-T6 Bare	8	4
B Ave	7075-T6 Bare	5.0	5.7
C1	2024-T3 Bare	3	7
C2	2024-T3 Bare	4	7
C3	2024-T3 Bare	4	7
C Ave	2024-T3 Bare	3.7	7.0
D1	2024-T3 Alclad	6	4
D2	2024-T3 Alclad	8	9
D3	2024-T3 Alclad	5	4
D Ave	2024-T3 Alclad	6.3	5.7

TABLE 9: COATING SYSTEM N ALUMINUM CORROSION RATING

Sandwich Configuration Letter	1"x 4" Aluminum Substrate Type	Corrosion Rating on 1"x 4" Aluminum Substrate After 2000-Hour Exposure	Corrosion Rating on 2"x 5" 2024-T3 Alclad Aluminum Substrate After 2000-Hour Exposure
A1	7075-T6 Alclad	8	6
A2	7075-T6 Alclad	8	5
A3	7075-T6 Alclad	10	5
A Ave	7075-T6 Alclad	8.7	5.3
B1	7075-T6 Bare	6	6
B2	7075-T6 Bare	5	6
B3	7075-T6 Bare	5	7
B Ave	7075-T6 Bare	5.3	6.3
C1	2024-T3 Bare	4	6
C2	2024-T3 Bare	5	7
C3	2024-T3 Bare	4	6
C Ave	2024-T3 Bare	4.3	6.3
D1	2024-T3 Alclad	8	5
D2	2024-T3 Alclad	10	4
D3	2024-T3 Alclad	7	5
D Ave	2024-T3 Alclad	8.3	4.7

TABLE 10: COATING SYSTEM O ALUMINUM CORROSION RATING

Sandwich Configuration Letter	1"x 4" Aluminum Substrate Type	Corrosion Rating on 1"x 4" Aluminum Substrate After 2000-Hour Exposure	Corrosion Rating on 2"x 5" 2024-T3 Alclad Aluminum Substrate After 2000-Hour Exposure
A1	7075-T6 Alclad	9	9
A2	7075-T6 Alclad	7	7
A3	7075-T6 Alclad	8	7
A Ave	7075-T6 Alclad	8.0	7.7
B1	7075-T6 Bare	10	9
B2	7075-T6 Bare	9	9
B3	7075-T6 Bare	9	7
B Ave	7075-T6 Bare	9.3	8.3
C1	2024-T3 Bare	4	9
C2	2024-T3 Bare	4	10
C3	2024-T3 Bare	4	9
C Ave	2024-T3 Bare	4.0	9.3
D1	2024-T3 Alclad	9	9
D2	2024-T3 Alclad	9	9
D3	2024-T3 Alclad	9	10
D Ave	2024-T3 Alclad	9.0	9.3

TABLE 11: COATING SYSTEM S ALUMINUM CORROSION RATING

Sandwich Configuration Letter	1"x 4" Aluminum Substrate Type	Corrosion Rating on 1"x 4" Aluminum Substrate After 2000-Hour Exposure	Corrosion Rating on 2"x 5" 2024-T3 Alclad Aluminum Substrate After 2000-Hour Exposure
A1	7075-T6 Alclad	0	1
A2	7075-T6 Alclad	1	0
A3	7075-T6 Alclad	0	0
A Ave	7075-T6 Alclad	0.3	0.3
B1	7075-T6 Bare	4	0
B2	7075-T6 Bare	4	1
B3	7075-T6 Bare	3	0
B Ave	7075-T6 Bare	3.7	0.3
C1	2024-T3 Bare	0	1
C2	2024-T3 Bare	0	1
C3	2024-T3 Bare	0	1
C Ave	2024-T3 Bare	0.0	1.0
D1	2024-T3 Alclad	1	0
D2	2024-T3 Alclad	1	1
D3	2024-T3 Alclad	1	0
D Ave	2024-T3 Alclad	1.0	0.3

TABLE 12: COATING SYSTEM T ALUMINUM CORROSION RATING

Sandwich Configuration Letter	1"x 4" Aluminum Substrate Type	Corrosion Rating on 1"x 4" Aluminum Substrate After 2000-Hour Exposure	Corrosion Rating on 2"x 5" 2024-T3 Alclad Aluminum Substrate After 2000-Hour Exposure
A1	7075-T6 Alclad	6	10
A2	7075-T6 Alclad	7	9
A3	7075-T6 Alclad	6	3
A Ave	7075-T6 Alclad	6.3	7.3
B1	7075-T6 Bare	7	9
B2	7075-T6 Bare	8	5
B3	7075-T6 Bare	8	9
B Ave	7075-T6 Bare	7.7	7.7
C1	2024-T3 Bare	10	6
C2	2024-T3 Bare	2	9
C3	2024-T3 Bare	1	6
C Ave	2024-T3 Bare	4.3	7.0
D1	2024-T3 Alclad	5	5
D2	2024-T3 Alclad	7	6
D3	2024-T3 Alclad	9	6
D Ave	2024-T3 Alclad	7.0	5.7

DISCUSSION:

A coating system needs to protect the entire substrate surface in service applications. Since most of the coating deficiencies seem to occur along panel edges or where fasteners have been installed, the dissimilar metals corrosion test was designed to exploit these observations. No coating system evaluated in this study, including the chromated controls, were capable of protecting all substrate surfaces included in this test. That is why the rating and ranking system was incorporated, providing as much information as possible on individual coating system deficiencies.

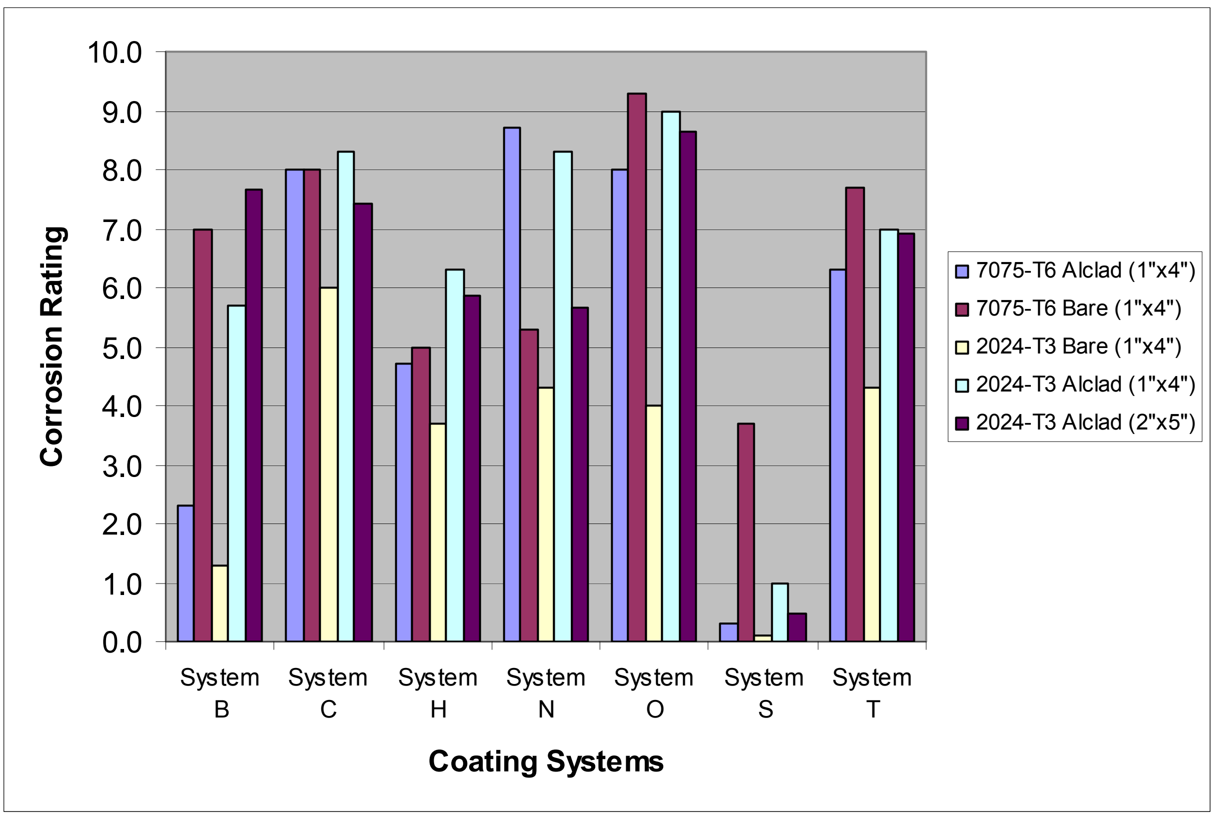
In Evaluation Area 1, the exterior aluminum surfaces were examined for signs of coating degradation due to direct salt fog exposure. After 2000 hours of salt fog, the top two coating systems with the best exterior appearance were the chromated controls. These systems were mostly defect-free, with only minor breaks observed in the protective coating systems. System H, System B and System T were consecutively rated as having less surface area covered by visible defects for the chrome-free systems, but they did not provide as much protection as the chromated control systems. Exterior surfaces on System N and System S were covered with so many blisters and coating breaks, these systems did not seem to provide much protection to the substrate for direct salt fog exposure. A representative from Akzo indicated the Mg-Rich primer requires a polyurethane topcoat when exposed directly to salt fog. Other test partners in this study would be looking at this system with polyurethane topcoat in salt fog.

In Evaluation Area 2, the faying aluminum surfaces in contact with the titanium panel were evaluated for galvanic attack and crevice corrosion. Each individual panel was rated on a scale of 0 to 10 in this evaluation, allowing a numerical comparison of corrosion ratings for each coating system and substrate. Average corrosion ratings and coating system ranks on various aluminum alloys are summarized in Table 13 and Figure 3.

TABLE 13: AVERAGE CORROSION RATING & RANK OF COATING SYSTEMS

Configuration ID	A	B	C	D	ALL	SUM	RANK
Coupon Size	1" x 4"	1" x 4"	1" x 4"	1" x 4"	2" x 5"	MIX	MIX
Aluminum Alloy	7075-T6 Alclad	7075-T6 Bare	2024-T3 Bare	2024-T3 Alclad	2024-T3 Alclad	ALL	ALL
System B	2.3	7.0	1.3	5.7	7.7	24.0	6
System C	8.0	8.0	6.0	8.3	7.4	37.7	2
System H	4.7	5.0	3.7	6.3	5.9	25.6	5
System N	8.7	5.3	4.3	8.3	5.7	32.3	3
System O	8.0	9.3	4.0	9.0	8.7	39.0	1
System S	0.3	3.7	0.1	1.0	0.5	5.6	7
System T	6.3	7.7	4.3	7.0	6.9	32.2	4
Overall Average	5.5	6.6	3.4	6.5	6.1	28.0	N/A

FIGURE 3: AVERAGE CORROSION RATING OF COATING SYSTEM FOR EACH ALUMINUMUM ALLOY



System C and System O were the chromated controls utilized in this study. It is not surprising that they were the top two ranked systems overall. It was also observed that all coating systems (including the chromated controls) underperformed on the 1"x 4" 2024-T3 Bare aluminum alloy. System N and System T clearly outperformed all other non-chrome systems in this study. System N performed notably better on the interior 1"x 4" 7075-T6 Alclad and 2024-T3 Alclad aluminum surfaces than other candidates, but blistered excessively where exposed directly to salt fog. System T performed consistently on both interior and exterior aluminum surfaces, and appears to provide more uniform corrosion inhibition typical of the chromated control systems.

What contribution the surface treatment had on the overall performance of the primer could not be well defined in this study. Additional testing is recommended to look at the synergistic effects of non-chrome surface treatment and primer for various aluminum alloys. Thin film sulfuric acid anodize with a hot water seal (MIL-A-8625 Type IIB) should also be considered to enhance corrosion inhibition, particularly on the 2024-T3 Bare aluminum alloy. Dissimilar metals corrosion testing on the coating systems identified in Table 14 will provide data to optimize the coating system's performance. This future study may be all that is necessary to identify a non-chrome coating system suitable for widespread use in permanent aerospace coating application areas.

TABLE 14: PROPOSED NON-CHROME COATING SYSTEMS FOR FUTURE STUDY

Surface Treatment	Primer
Pantheon PreKote	Akzo Mg-Rich Primer
Henkel Alodine 5700	Akzo Mg-Rich Primer
BoeGel EP-II (AC-131-CB)	Akzo Mg-Rich Primer
MIL-A-8625 Type IIB	Akzo Mg-Rich Primer
Pantheon PreKote	Akzo Sicopoxy 577-630
Henkel Alodine 5700	Akzo Sicopoxy 577-630
BoeGel EP-II (AC-131-CB)	Akzo Sicopoxy 577-630
MIL-A-8625 Type IIB	Akzo Sicopoxy 577-630

CONCLUSION:

Dissimilar metals corrosion is a severe test requirement historically utilized to evaluate interior primers used on Douglas Heritage commercial aircraft. Interior primers are intended to protect the aircraft structure throughout the entire service life of the vehicle. Non-chrome coating systems in this study were not found to offer overall equivalent corrosion protection as the chromated control systems. This finding suggests that further development of non-chrome coating technology is recommended before use in permanent, interior aircraft locations where access and inspection may be limited.

On aluminum surfaces exposed directly to salt fog, System H, System B and System T were consecutively rated as having less surface area covered by visible defects for the chrome-free systems, but they offered significantly less protection than either chromated control system. Exterior surfaces on System N and System S were covered with so many blisters and coating breaks, these systems did not seem to provide much protection to the substrate for direct salt fog exposure. System N did not have the same advantages of System S which was topcoated with a polyurethane finish. A polyurethane topcoat on System N may have eliminated this concern.

On faying aluminum surfaces, two non-chrome systems outperformed all others in this study. They were System N (Pantheon Pre-Kote with Akzo Mg-Rich Primer) and System T (Henkel Alodine 5700 with Akzo Sicopoxy 577-630). System N performed well on 2024-T3 Alclad and 7075-T6 Alclad aluminum that was not exposed directly to salt fog. System T performed consistently in direct salt fog exposures, and appears to provide a more uniform corrosion inhibition typical of the chromated control systems.

All coating systems, including the chromated controls, underperformed while protecting the 2024-T3 Bare aluminum alloy. Thin film sulfuric acid anodize with a hot water seal (MIL-A-8625 Type IIB) should be evaluated to enhance corrosion inhibition on this alloy. Additional testing is recommended to look for potential synergistic effects between non-chrome surface treatments and primers to identify a non-chrome coating system capable of widespread use in aerospace applications.

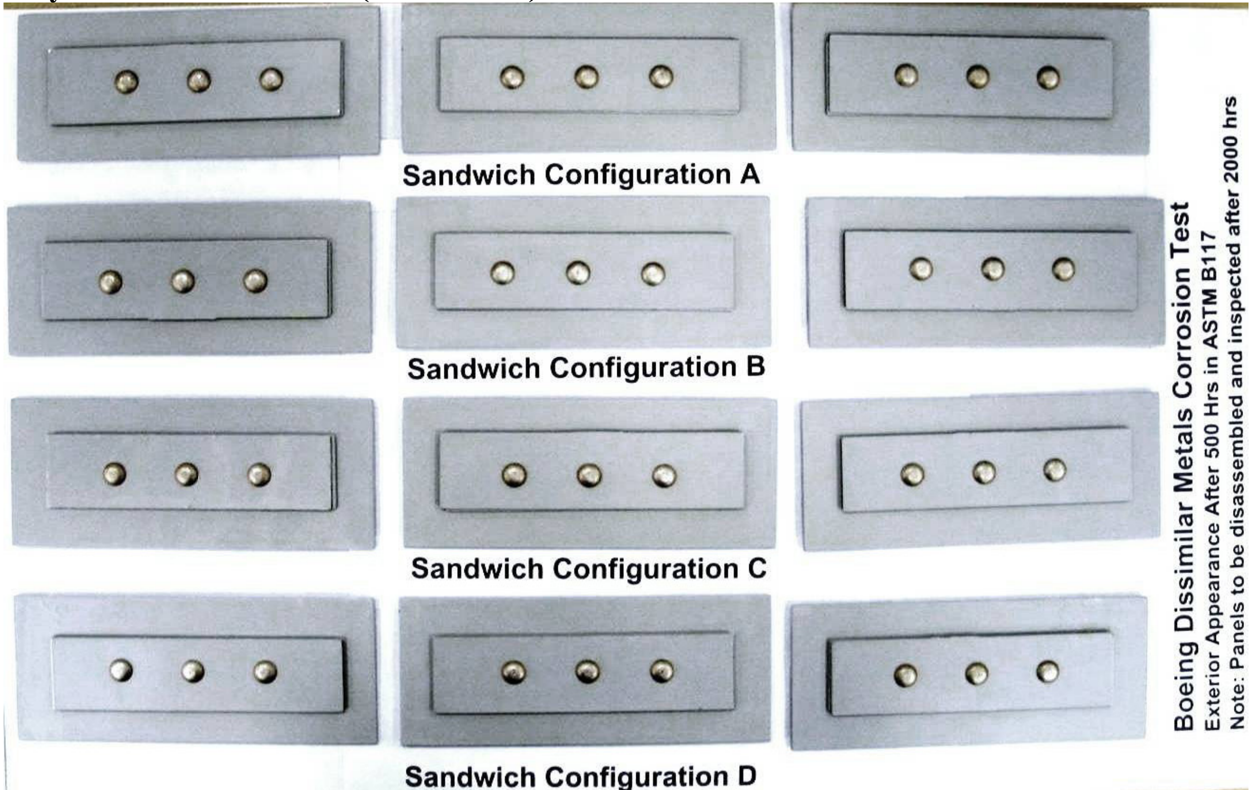
REFERENCES:

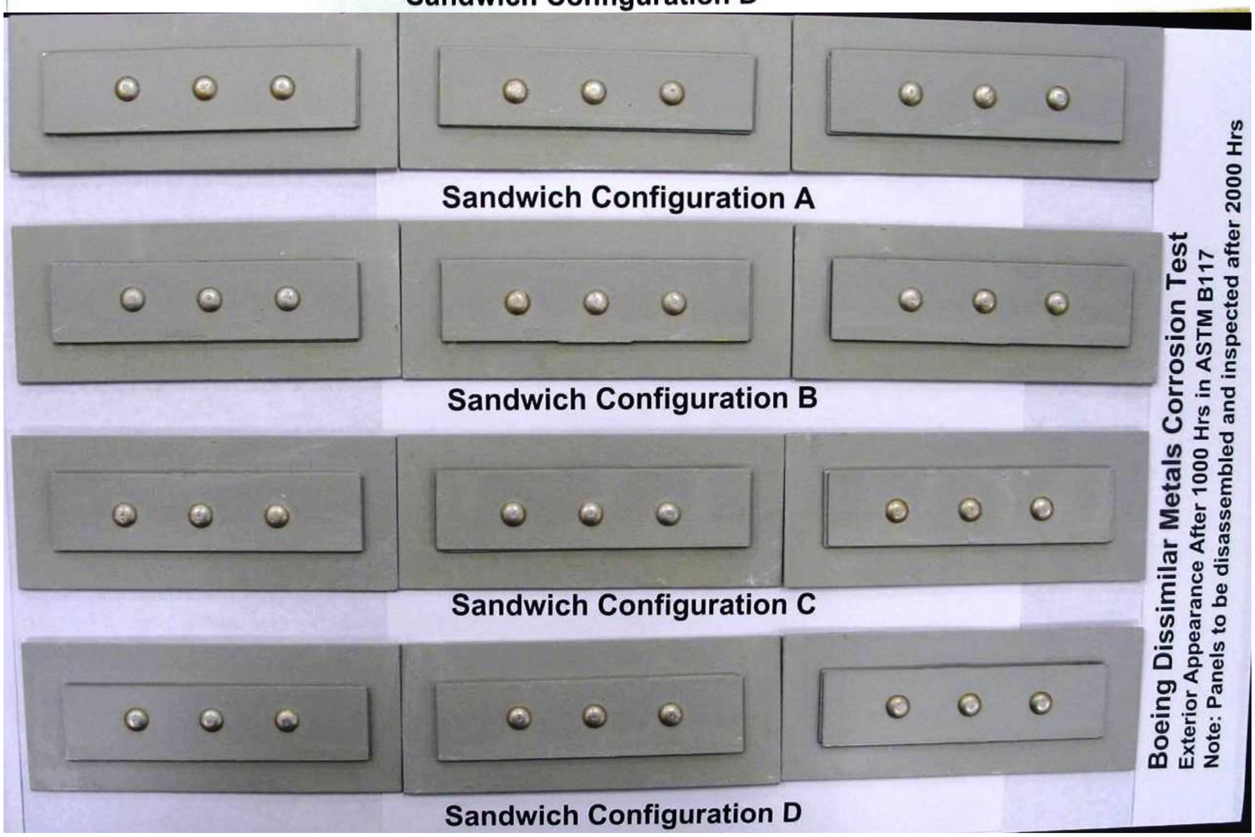
ASTM B 117 – Standard Practice for Operating Salt Spray (Fog) Apparatus.
DMS 1786 – Douglas Material Specification for Primer, Fluid Resistant.
MIL-A-8625 – Anodic Coatings for Aluminum and Aluminum Alloys.
MIL-C-5541 – Chemical Conversion Coating on Aluminum and Aluminum Alloys.
MIL-P-23377 – Primer Coatings, Epoxy, High Solids.
MIL-P-53022 – Primer, Epoxy Coating, Corrosion Inhibiting, Lead and Chromate Free.

ATTACHMENTS:

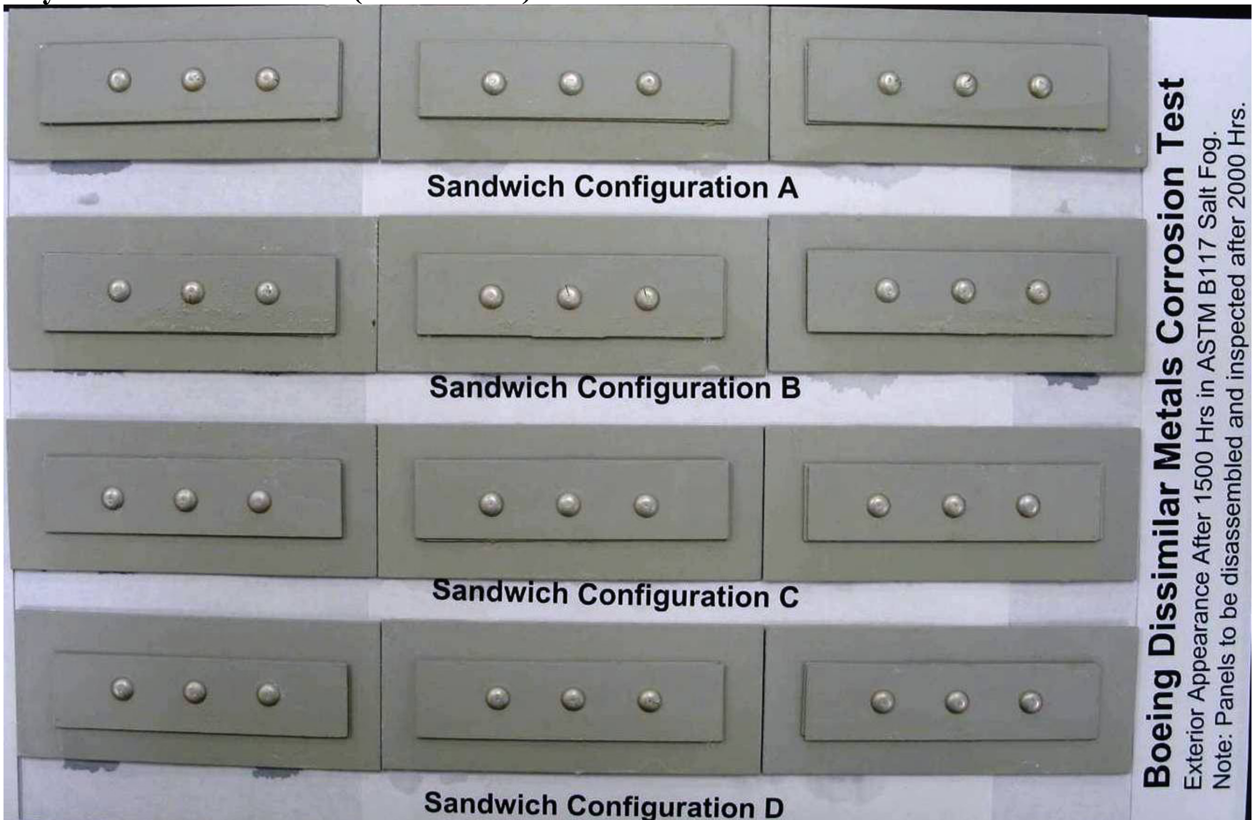
Coating System Sandwich Panel Photographs at each 500-Hour Increment of Salt Fog Exposure.
Aluminum Faying Surface Photographs from Each Sandwich Configuration after 2000 Hours of Salt Fog Exposure.

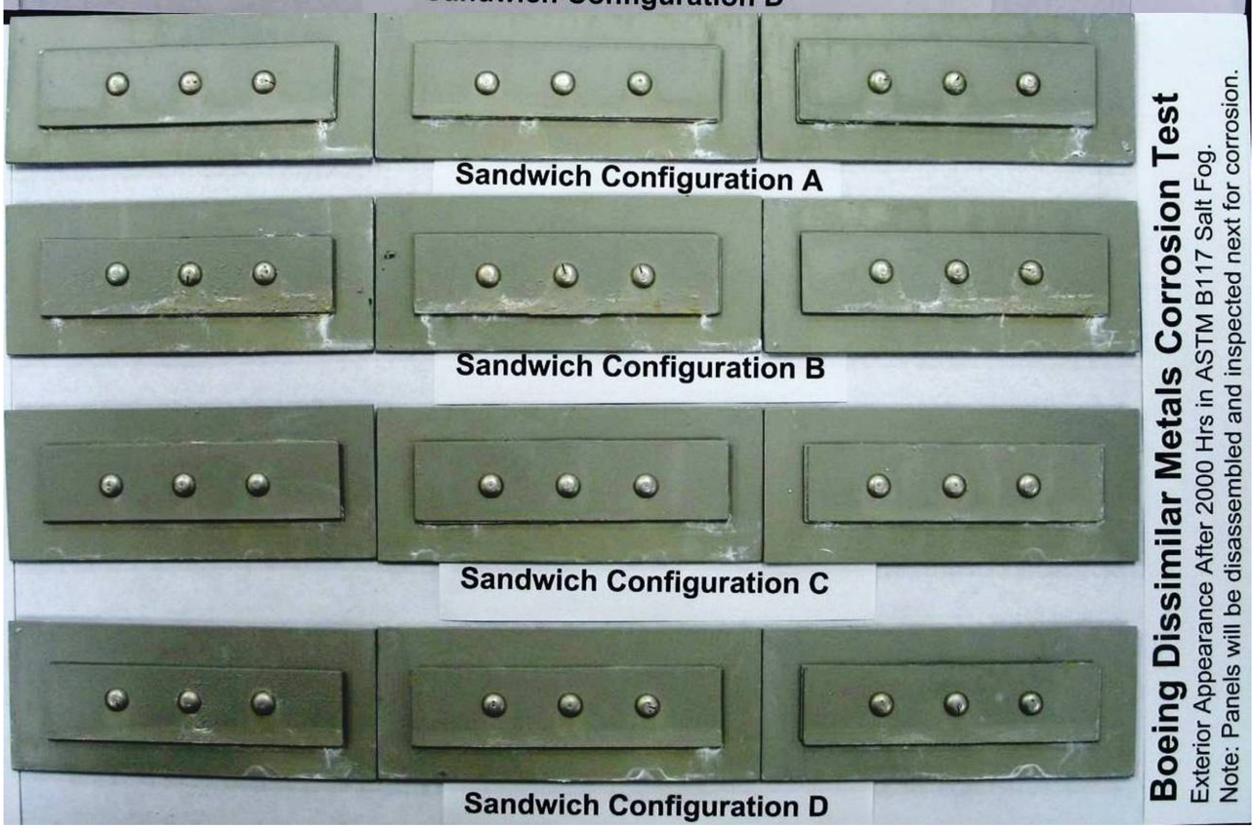
System B: BoeGel EPII (AC-131-CB) with DuPont Corlan 13570S at 500 & 1000 Hours





System B: BoeGel EPII (AC-131-CB) with DuPont Corlan 13570S at 1500 & 2000 Hours

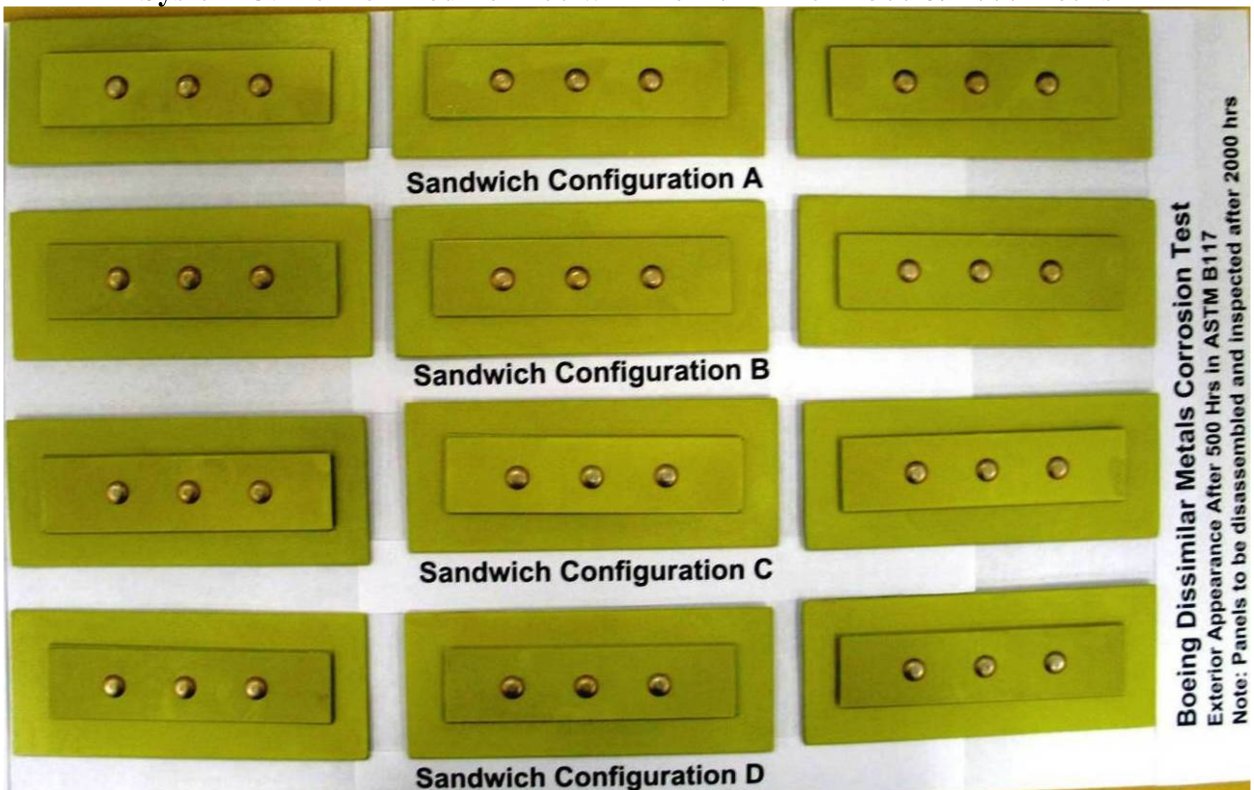


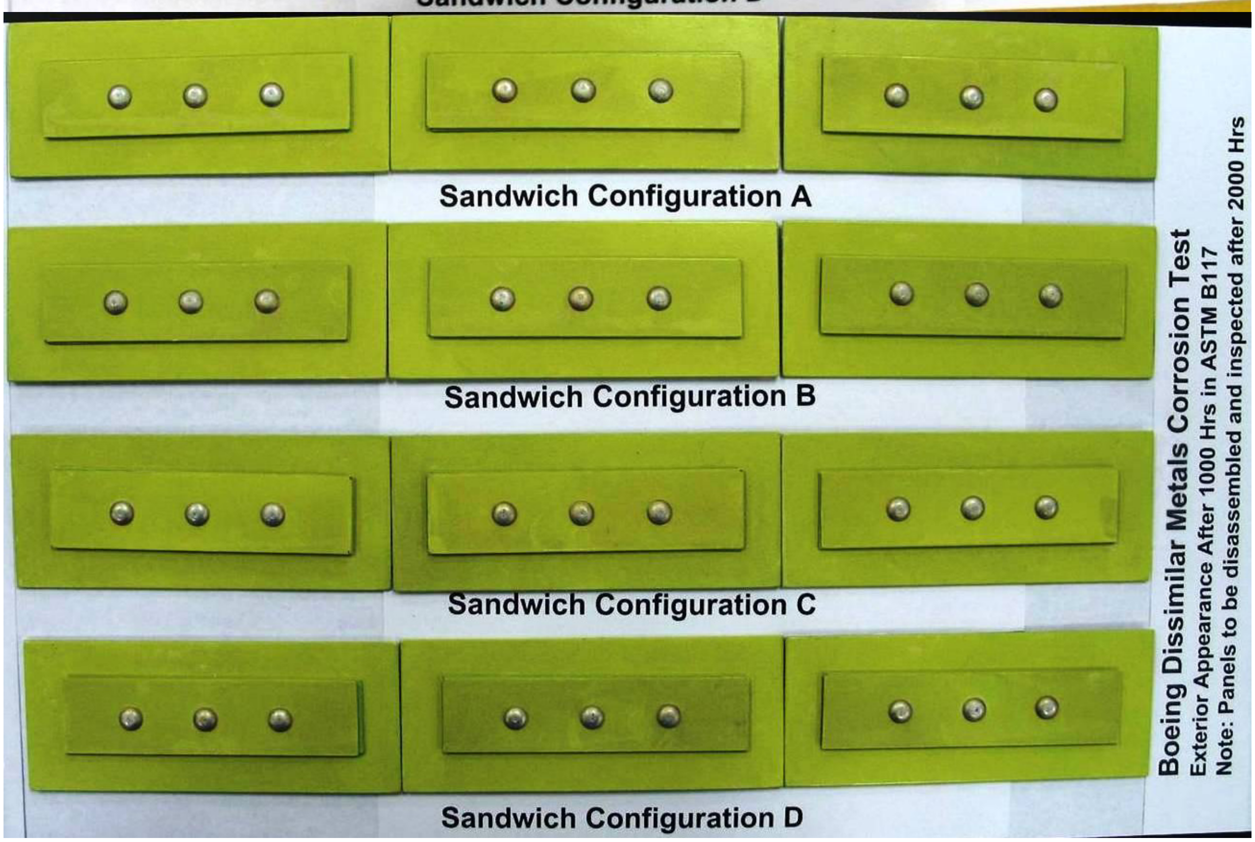


System B: BoeGel EPII (AC-131-CB) with DuPont Corlan 13570S Sandwich Configuration A&B Aluminum Faying Surfaces at 2000 Hours

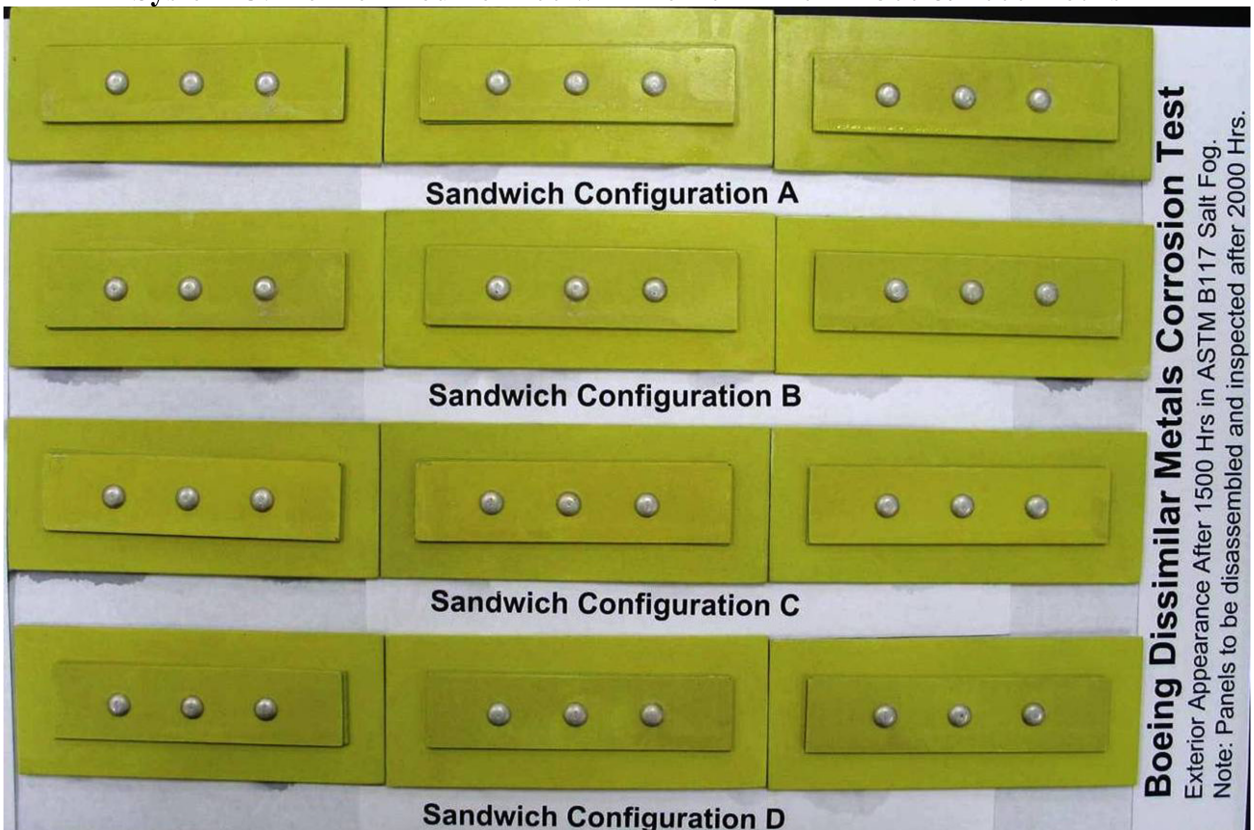
System B: BoeGel EPII (AC-131-CB) with DuPont Corlan 13570S Sandwich Configuration C&D Aluminum Faying Surfaces at 2000 Hours

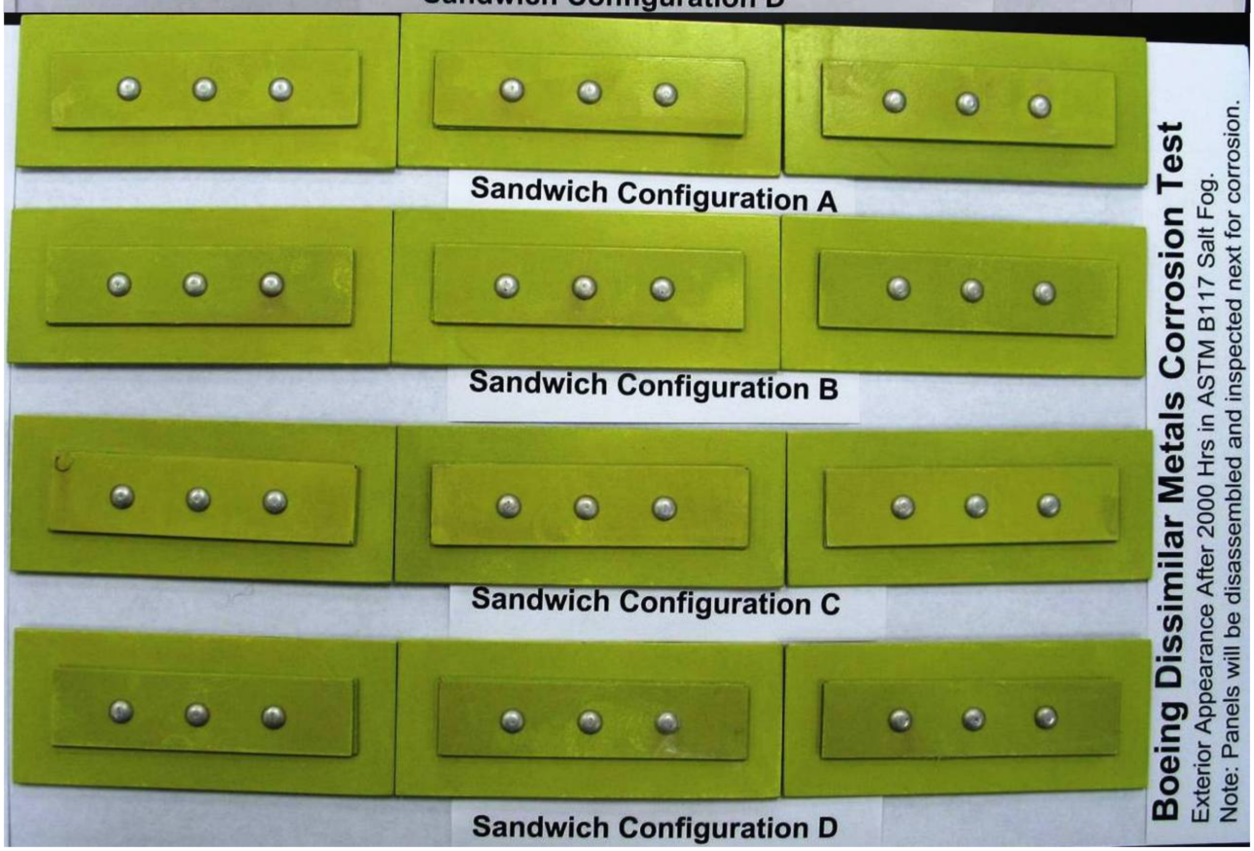
System C: Henkel Alodine 1200 with Deft 02-Y-40 at 500 & 1000 Hours





System C: Henkel Alodine 1200 with Deft 02-Y-40 at 1500 & 2000 Hours

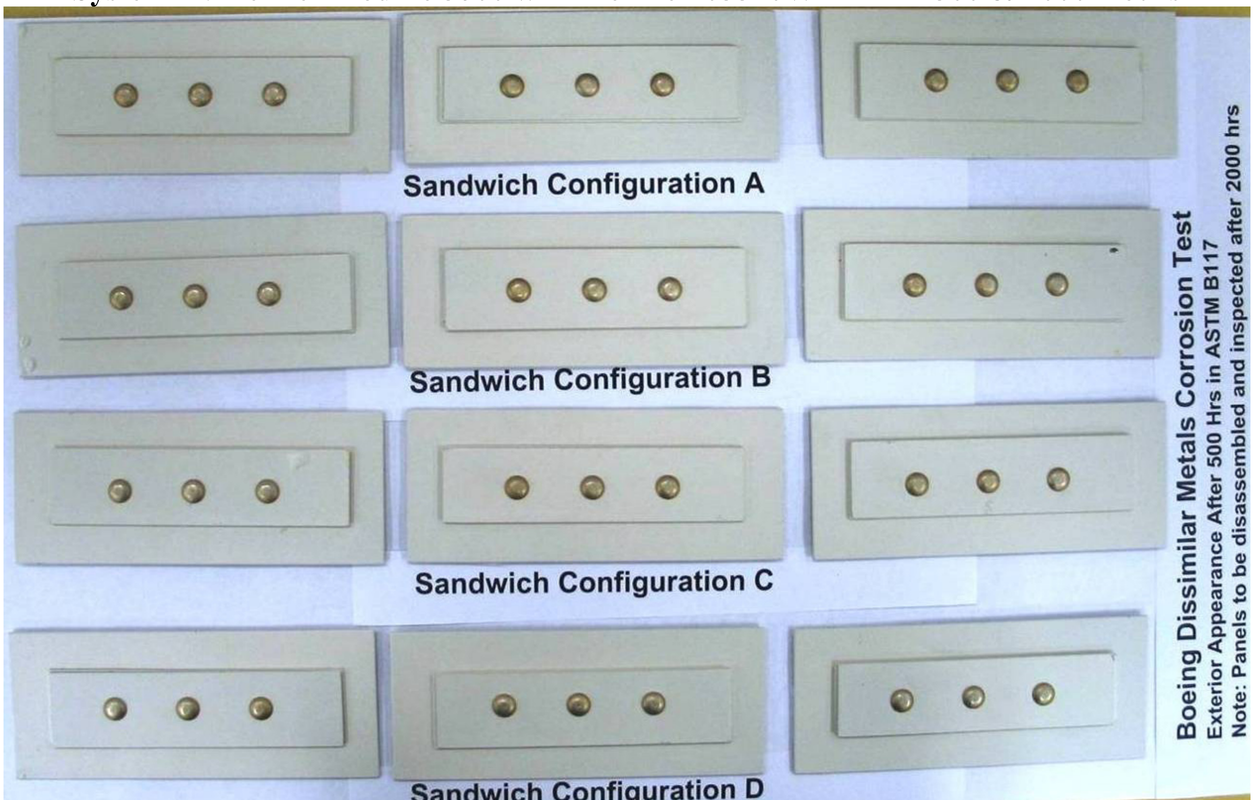


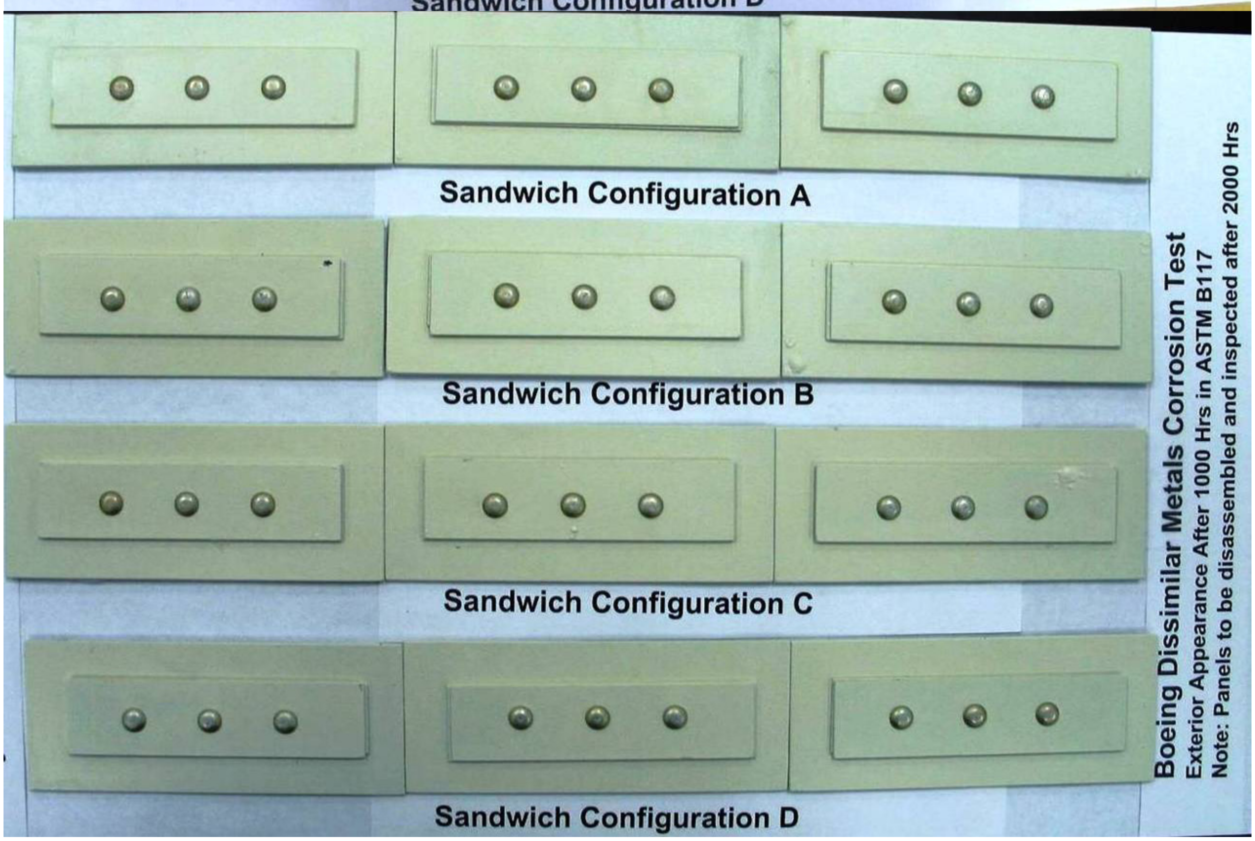


System C: Henkel Alodine 1200 with Deft 02-Y-40 Sandwich Configuration A&B Aluminum Faying Surfaces at 2000 Hours

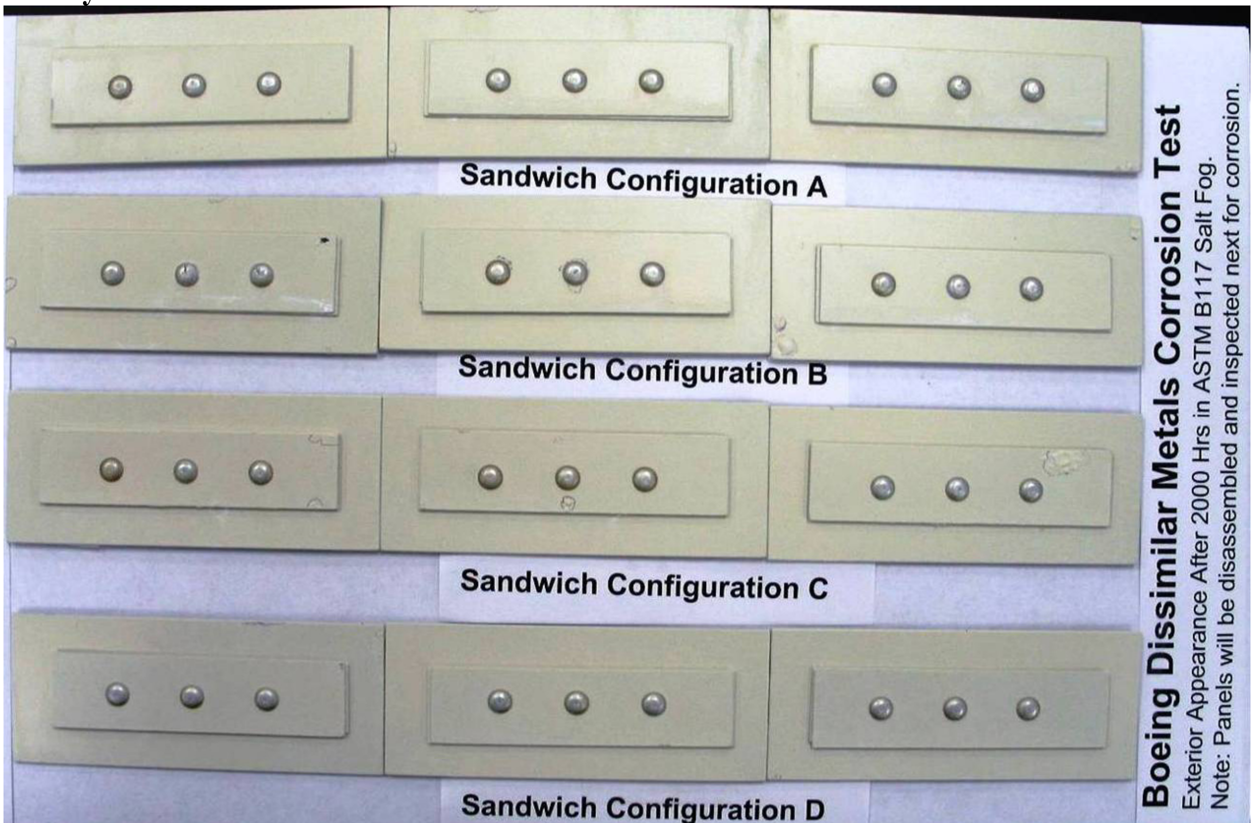
System C: Henkel Alodine 1200 with Deft 02-Y-40 Sandwich Configuration C&D Aluminum Faying Surfaces at 2000 Hours

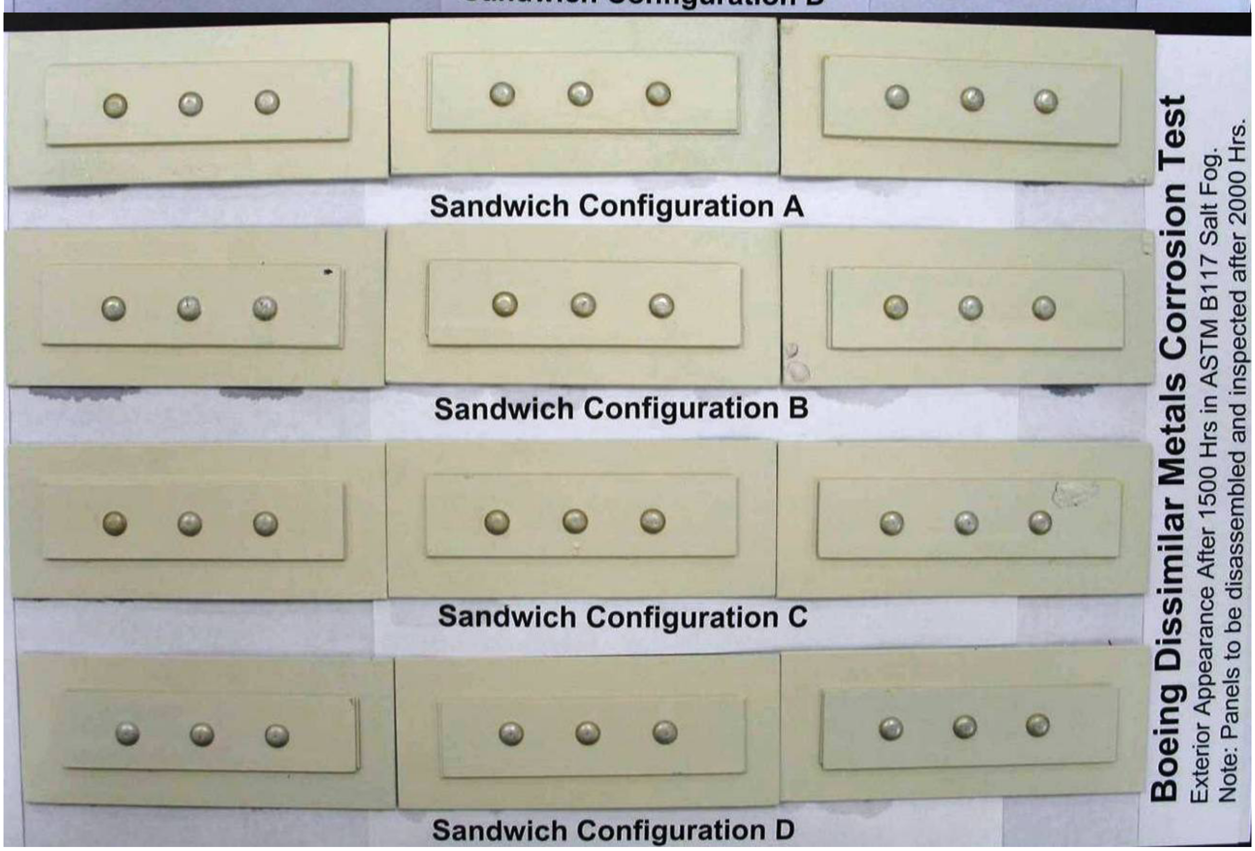
System H: Henkel Alodine 5700 with Hentzen 05510WEP-X at 500 & 1000 Hours





System H: Henkel Alodine 5700 with Hentzen 05510WEP-X at 1500 & 2000 Hours

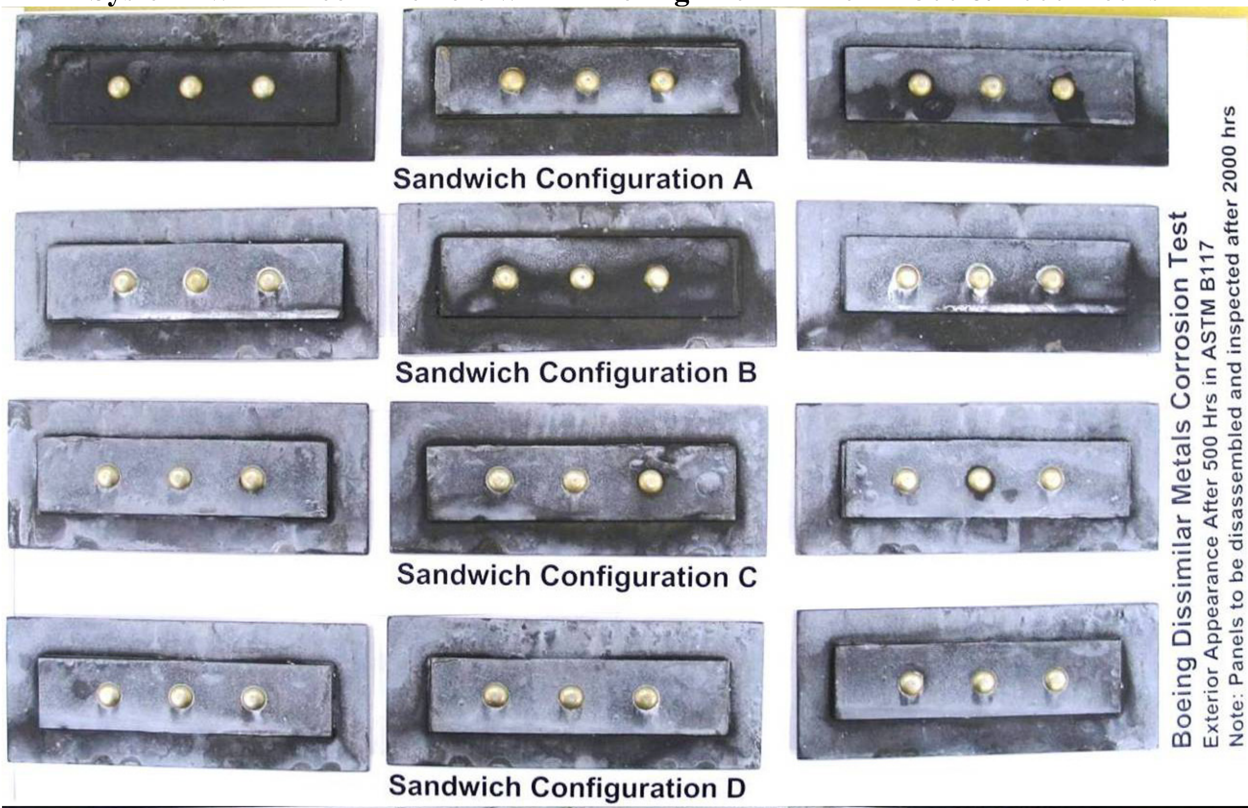


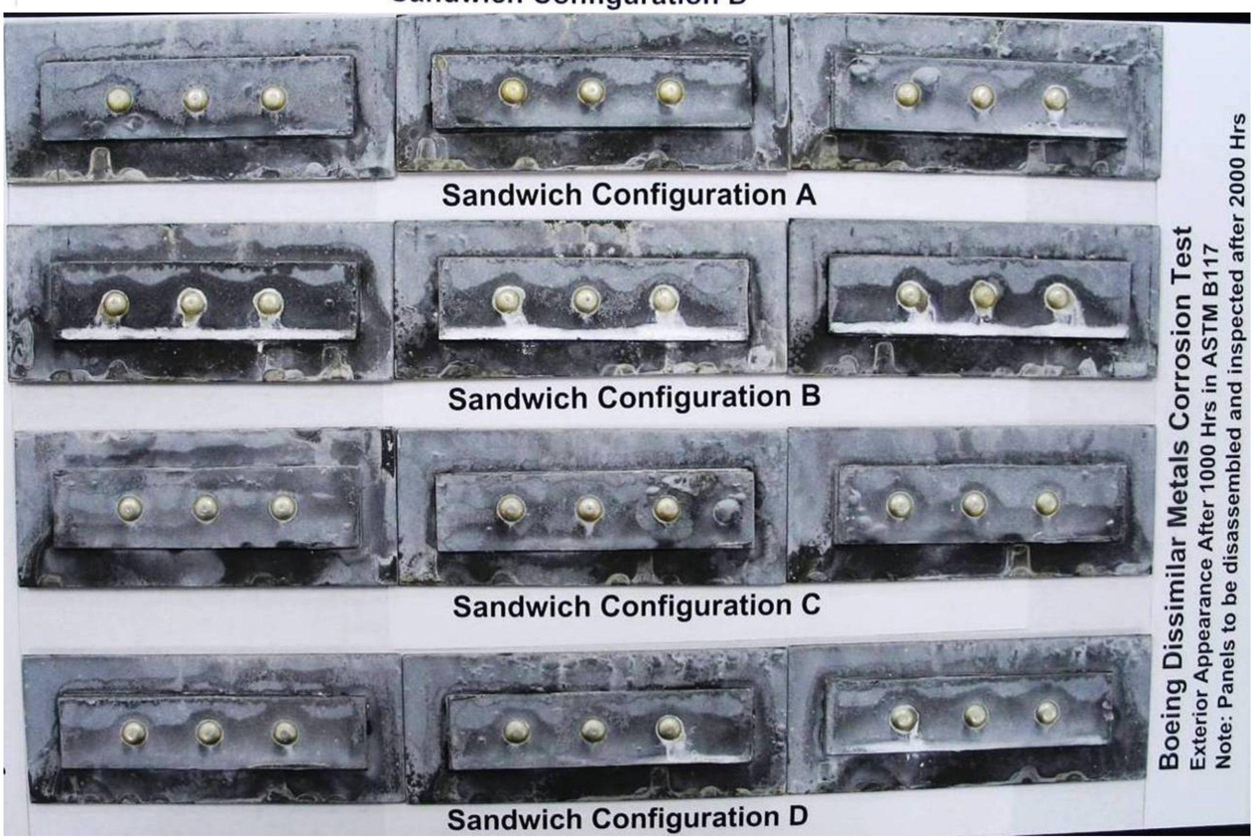


System H: Henkel Alodine 5700 with Hentzen 05510WEP-X Sandwich Configuration A&B Aluminum Faying Surfaces at 2000 Hours

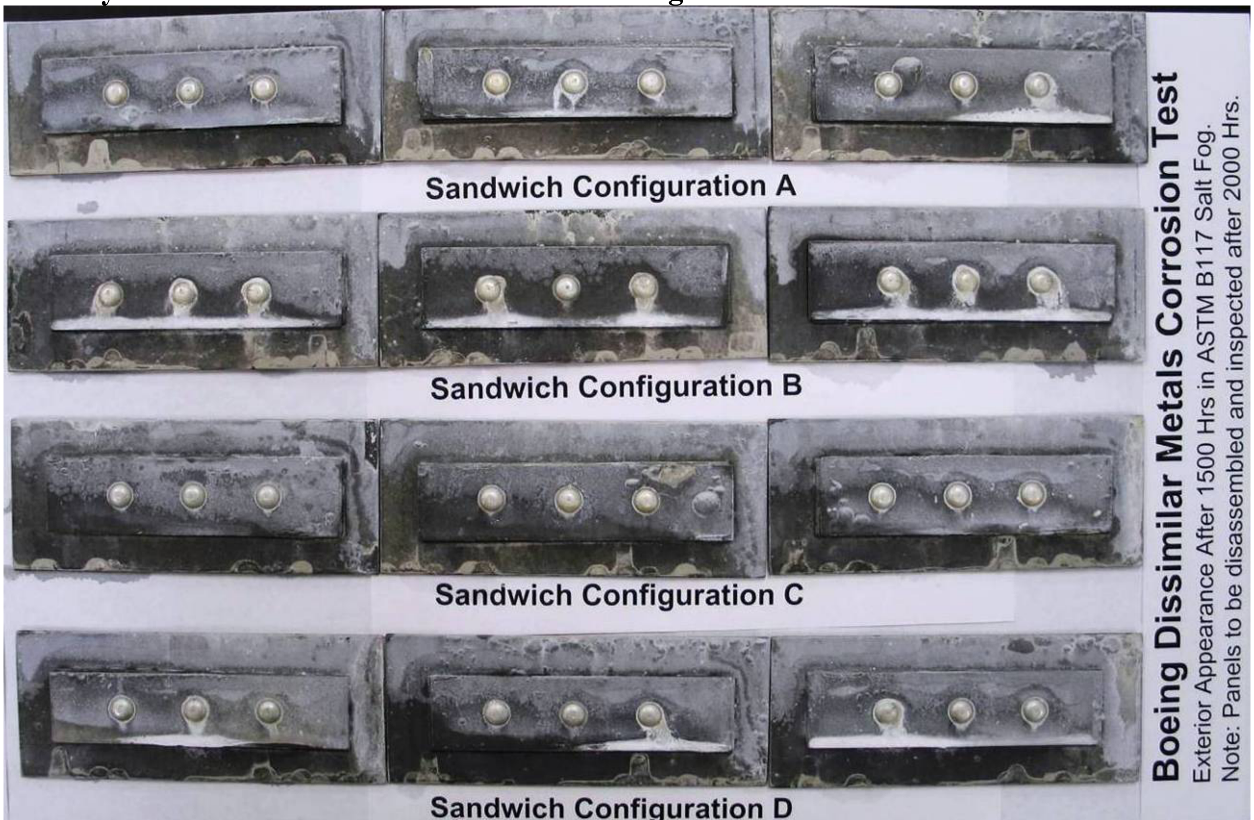
System H: Henkel Alodine 5700 with Hentzen 05510WEP-X Sandwich Configuration C&D Aluminum Faying Surfaces at 2000 Hours

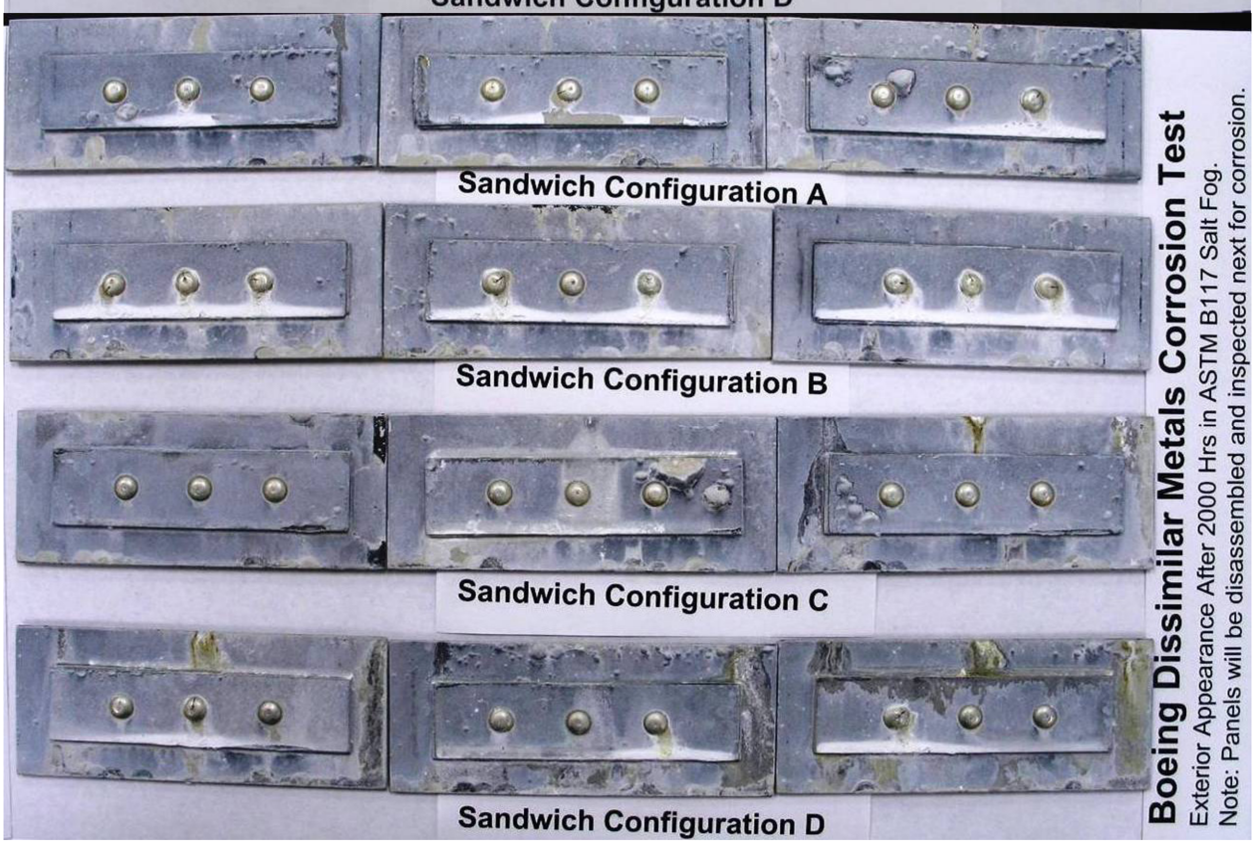
System N: Pantheon PreKote with Akzo Mg-Rich Primer at 500 & 1000 Hours





System N: Pantheon PreKote with Akzo Mg-Rich Primer at 1500 & 2000 Hours

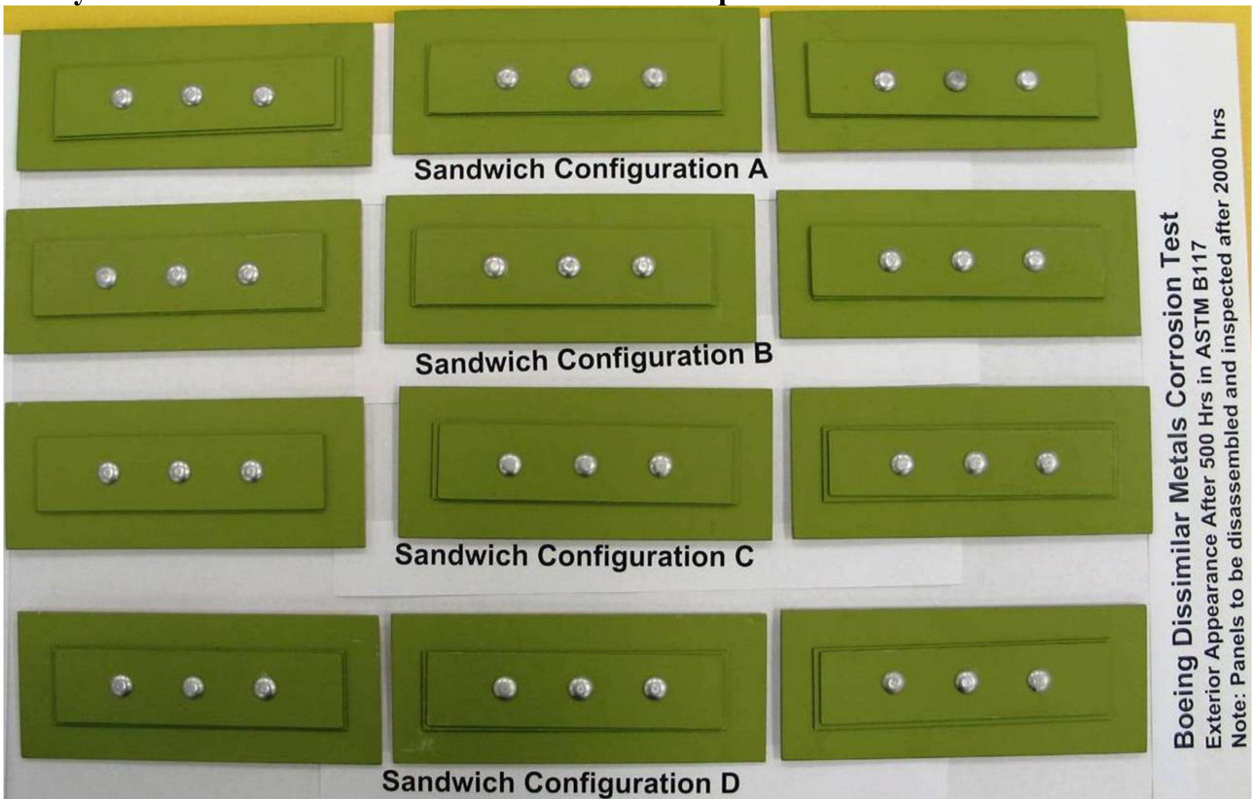


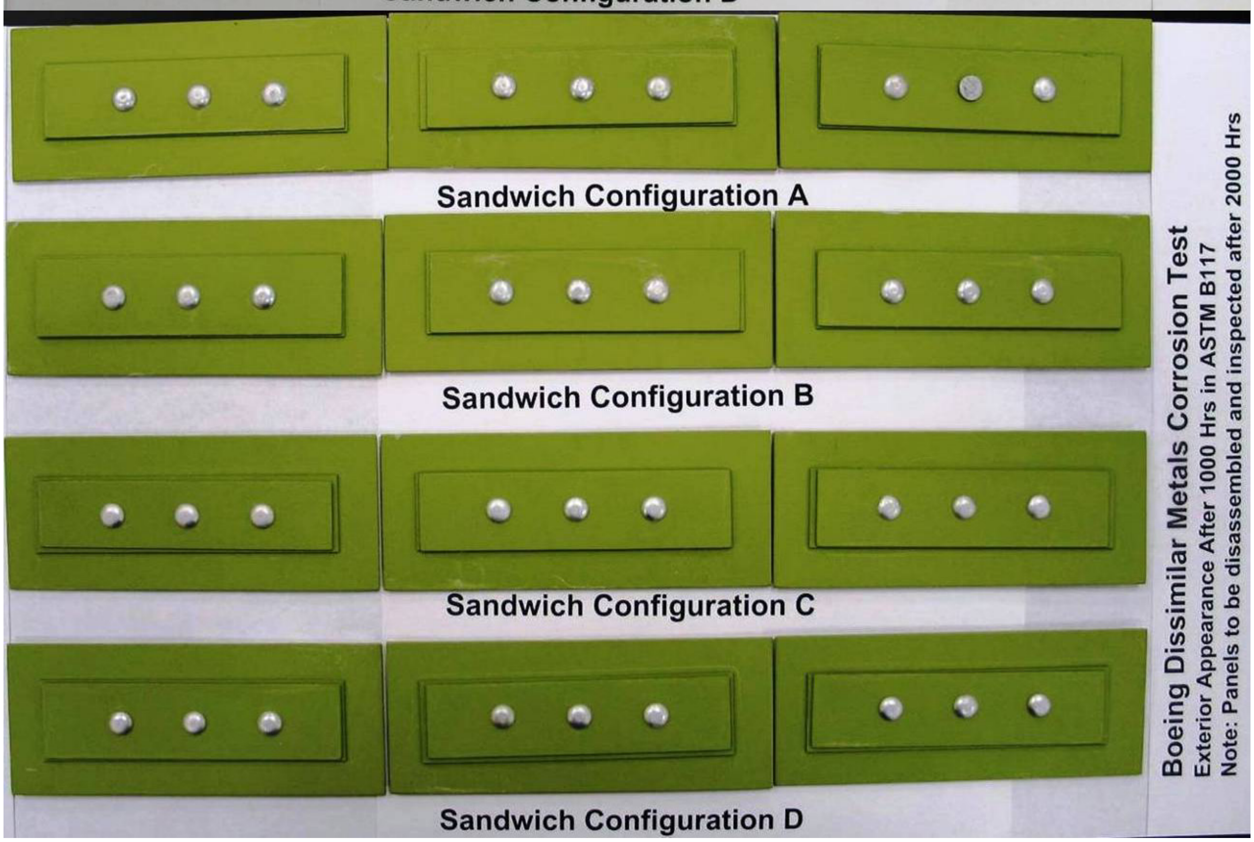


System N: Pantheon PreKote with Akzo Mg-Rich Primer Sandwich Configuration A&B Aluminum Faying Surfaces at 2000 Hours

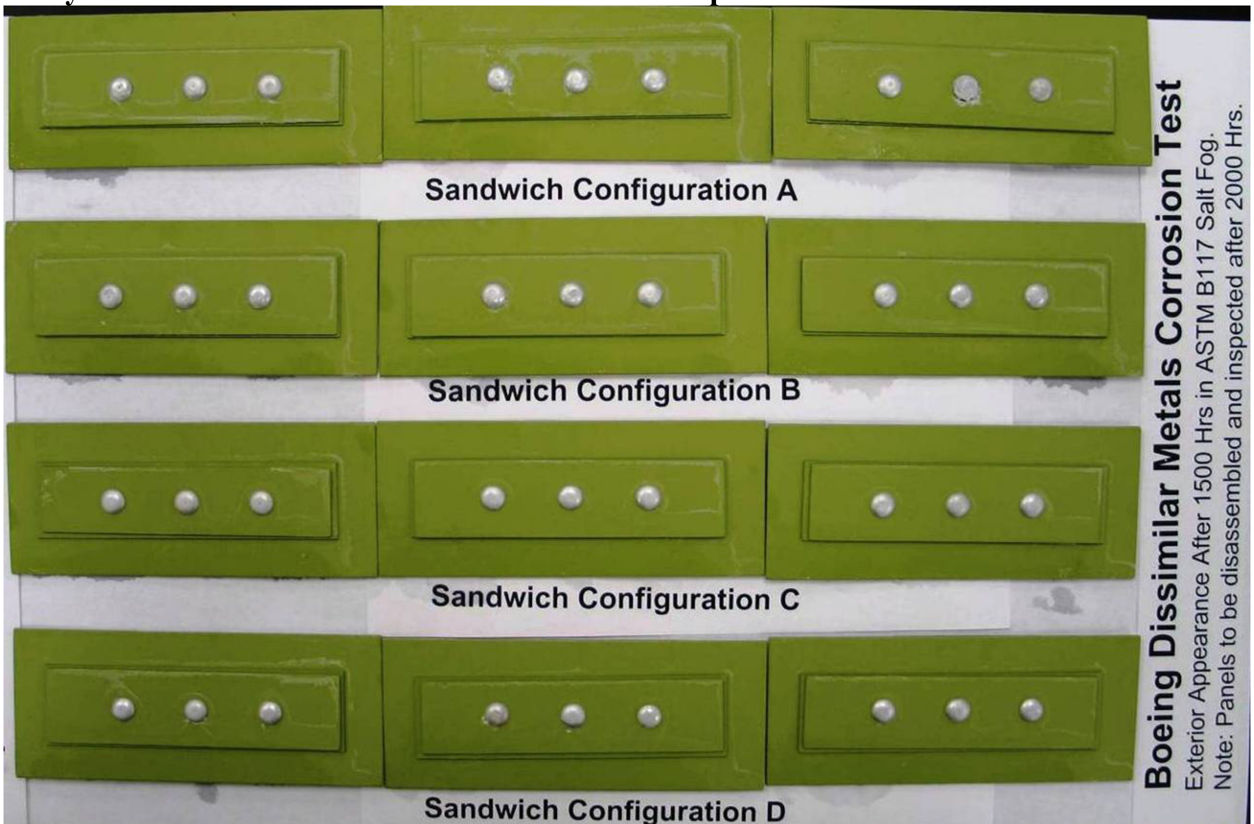
System N: Pantheon PreKote with Akzo Mg-Rich Primer Sandwich Configuration C&D Aluminum Faying Surfaces at 2000 Hours

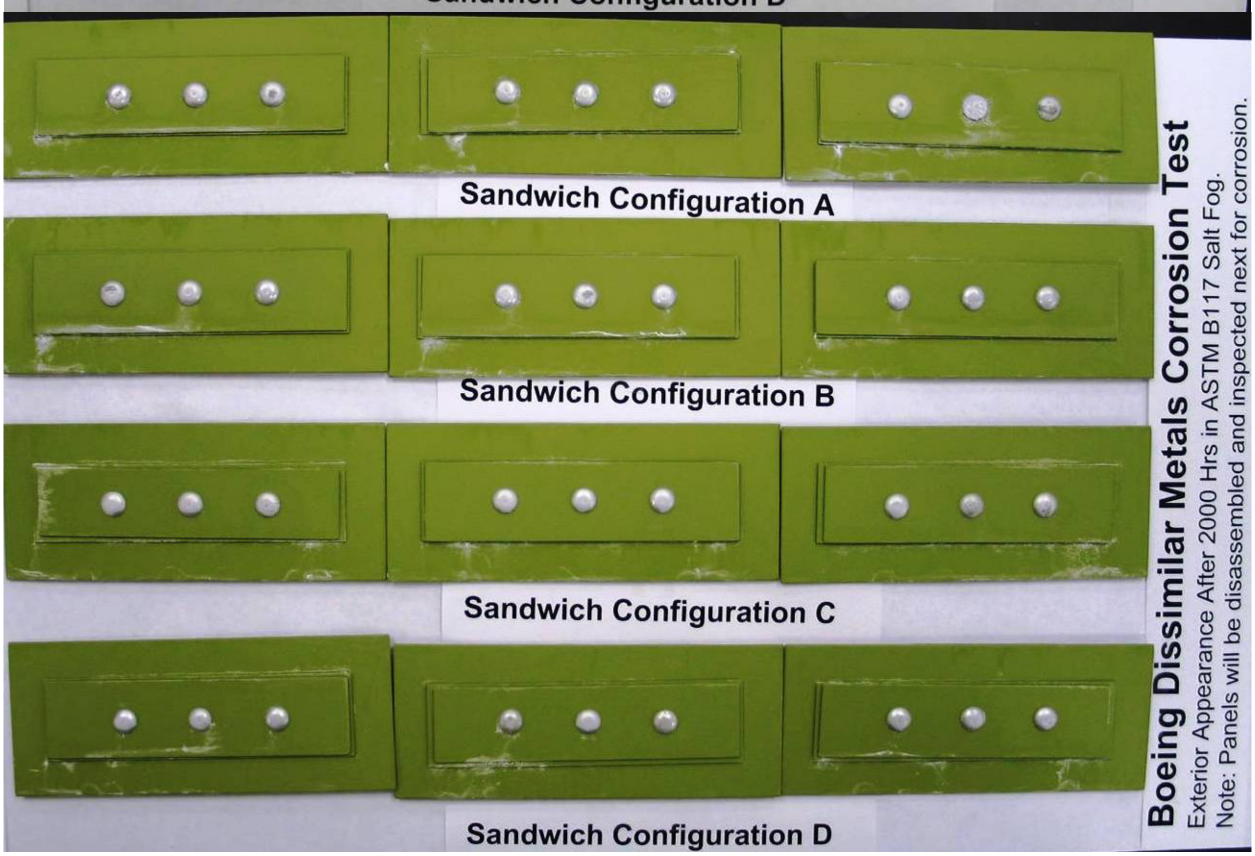
System O: Henkel Alodine 1200 with PPG Aerospace 515K012 at 500 & 1000 Hours



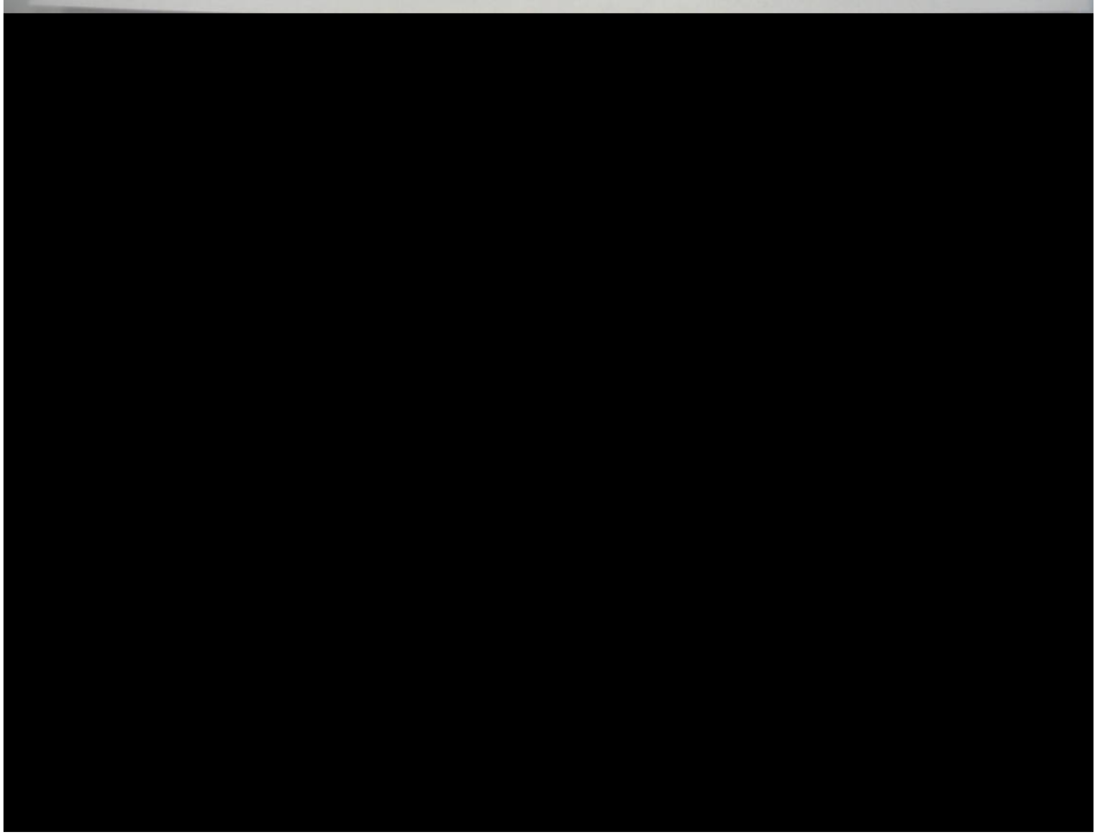


System O: Henkel Alodine 1200 with PPG Aerospace 515K012 at 1500 & 2000 Hours

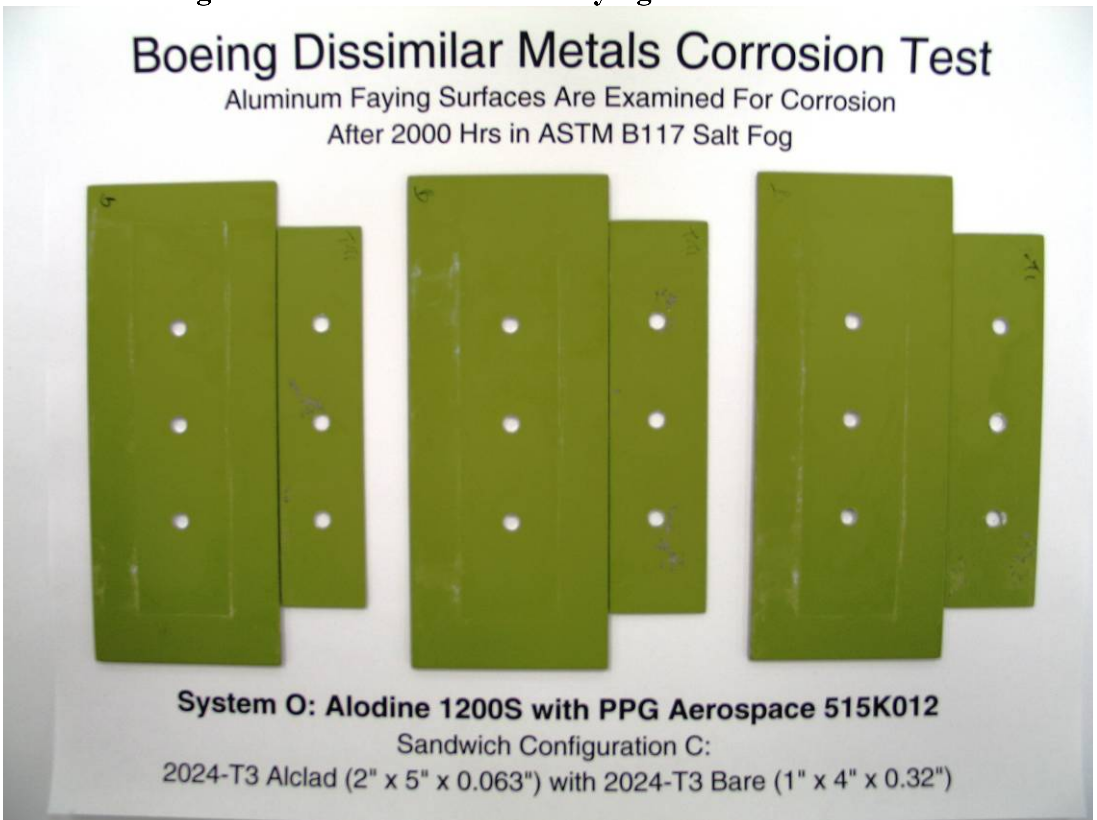


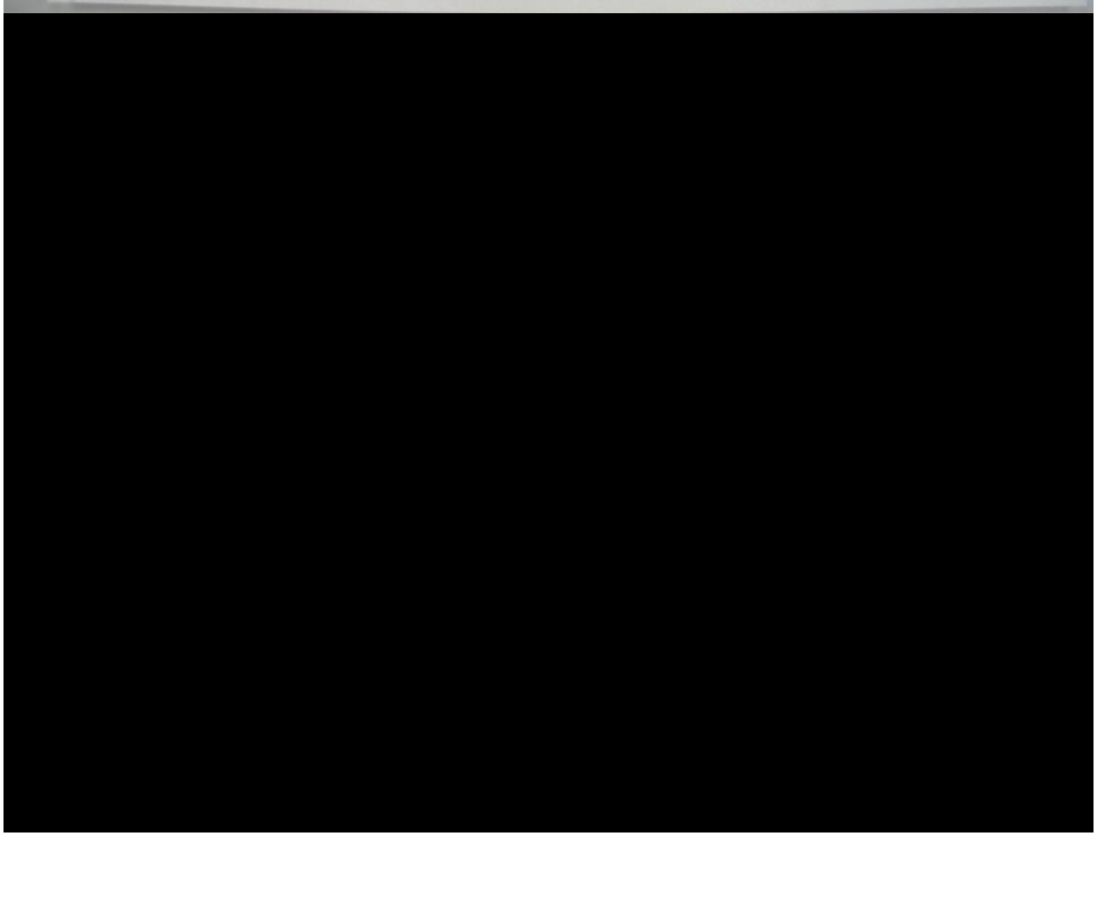


System O: Henkel Alodine 1200 with PPG Aerospace 515K012 Sandwich Configuration A&B Aluminum Faying Surfaces at 2000 Hours

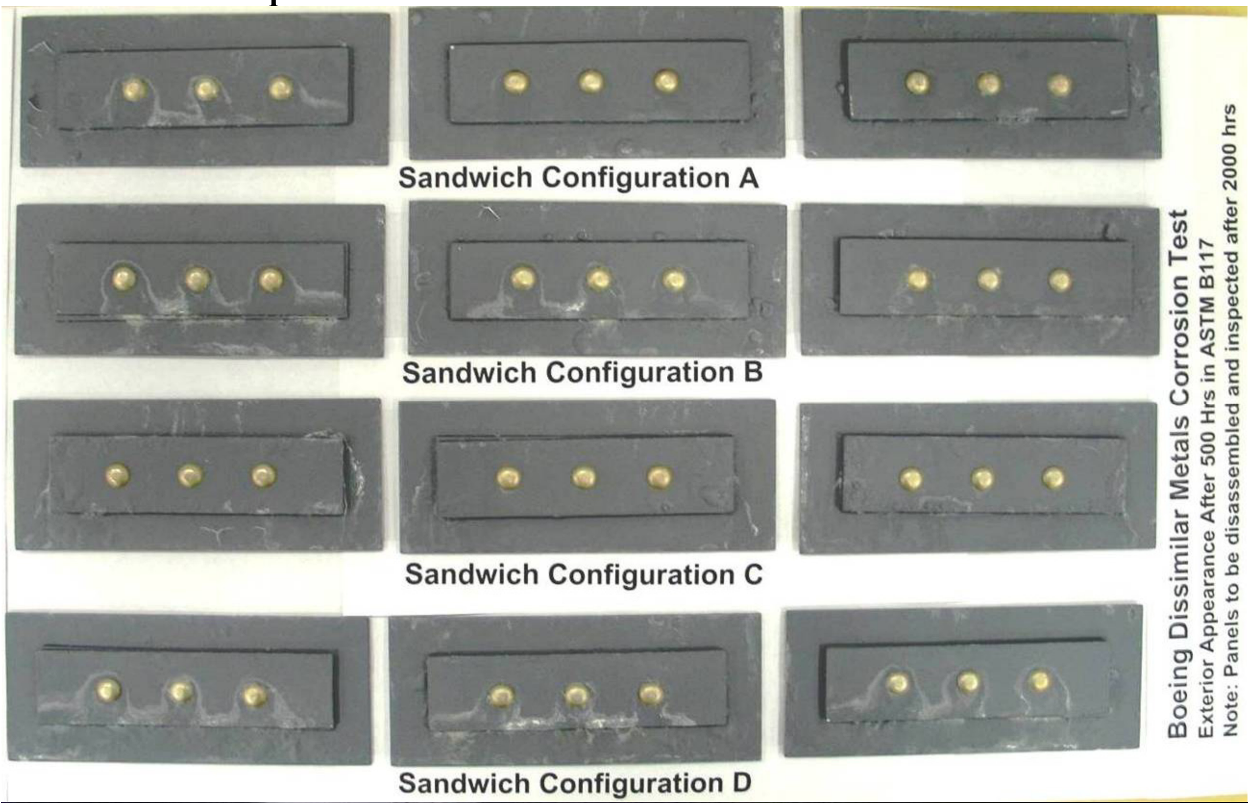


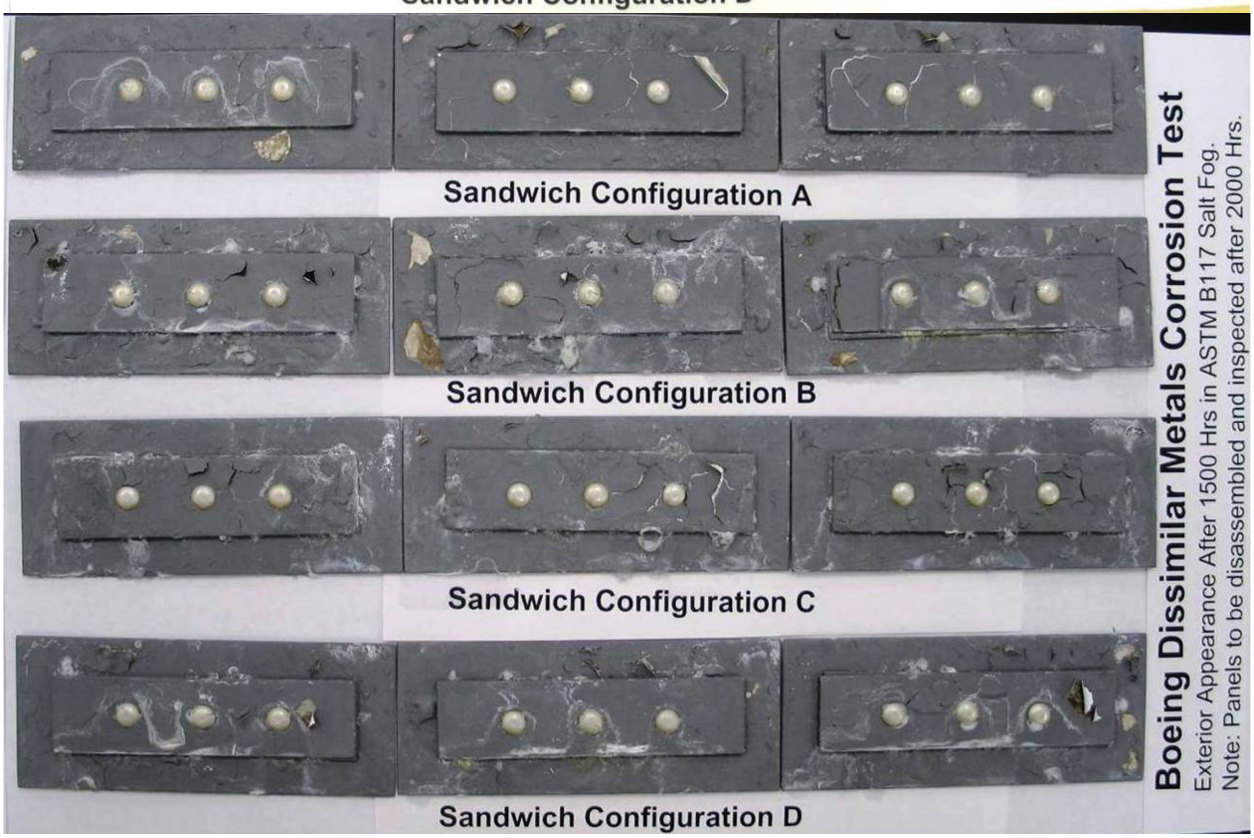
System O: Henkel Alodine 1200 with PPG Aerospace 515K012 Sandwich Configuration C&D Aluminum Faying Surfaces at 2000 Hours



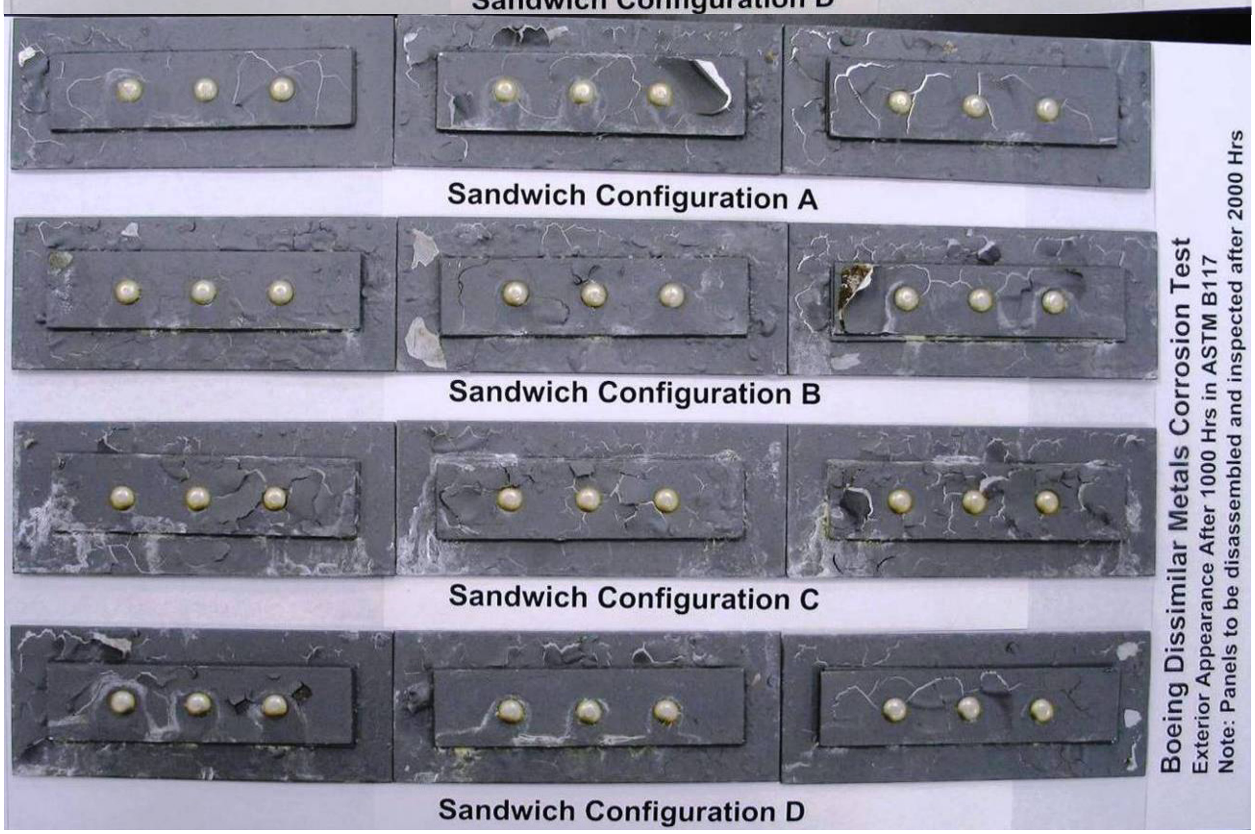


System S: Pantheon PreKote with AquaSur Tech Crosslinker & AquaSur Tech AST-D45-AMS-MO at 500 & 1000 Hours



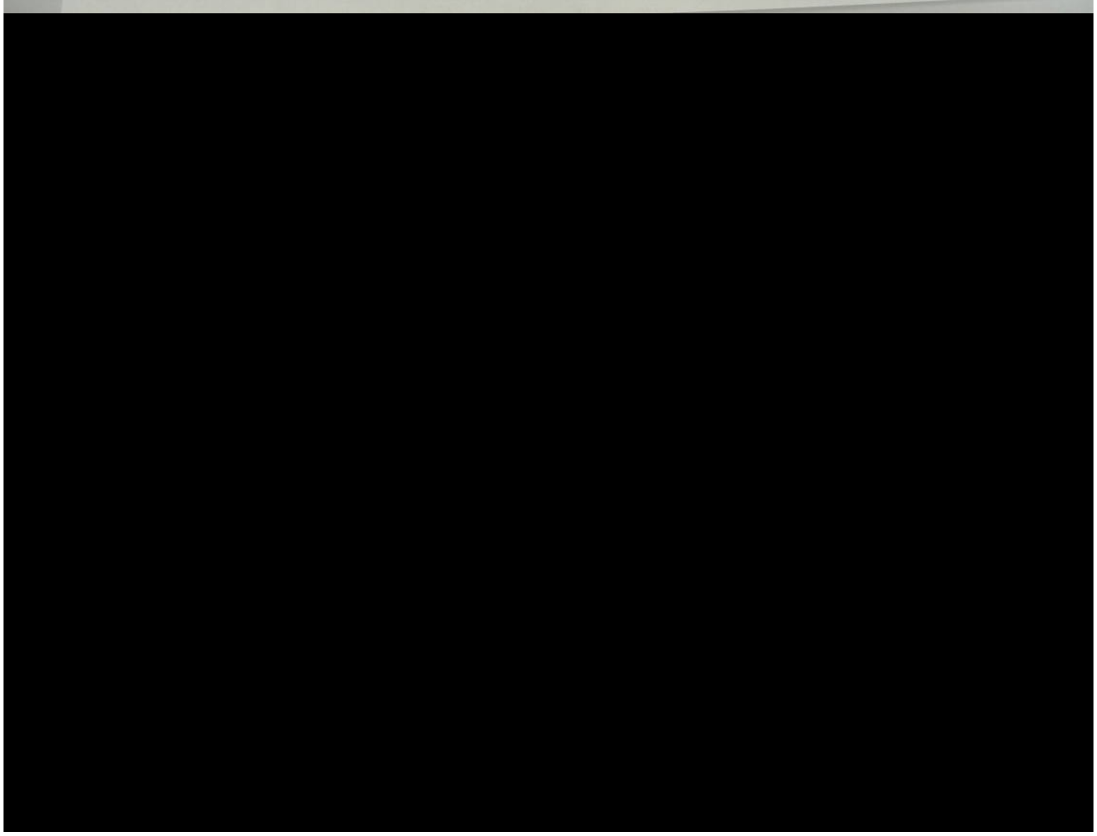


System S: Pantheon PreKote with AquaSur Tech Crosslinker & AquaSur Tech AST-D45-AMS-MO at 1500 & 2000 Hours

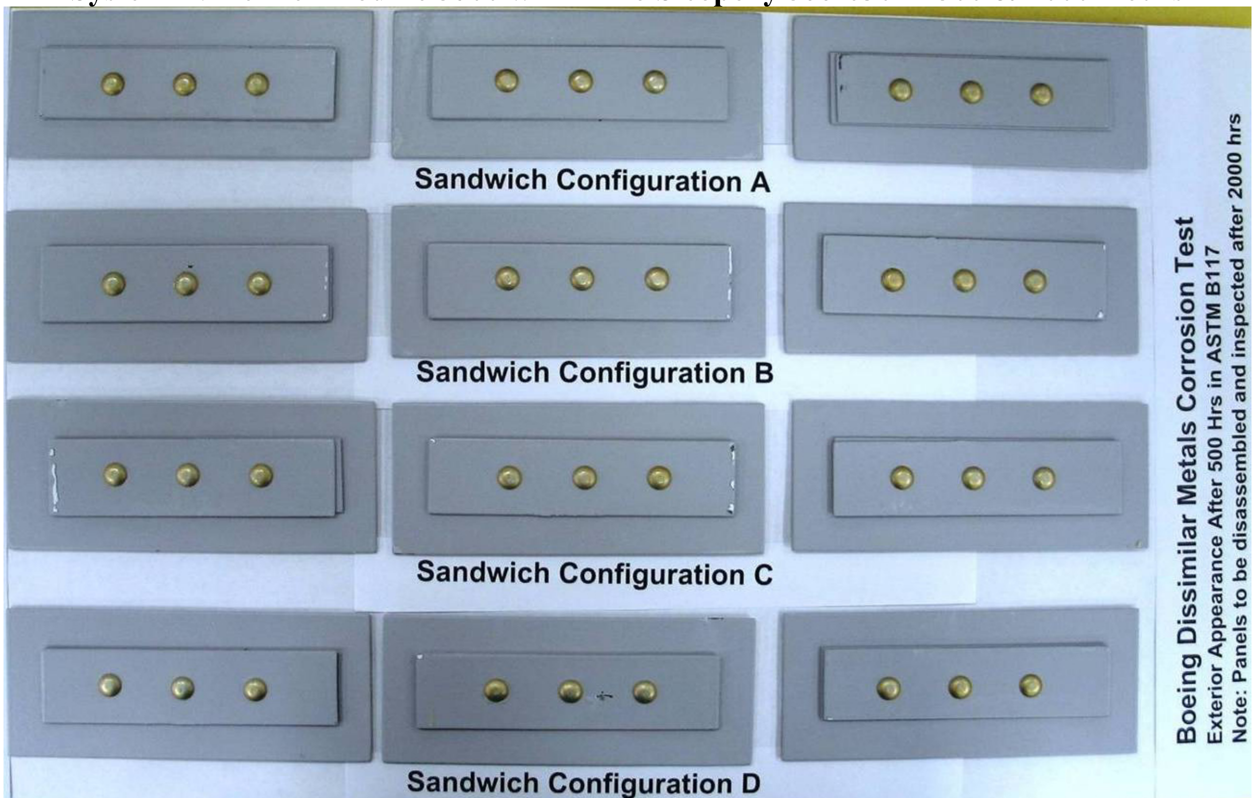


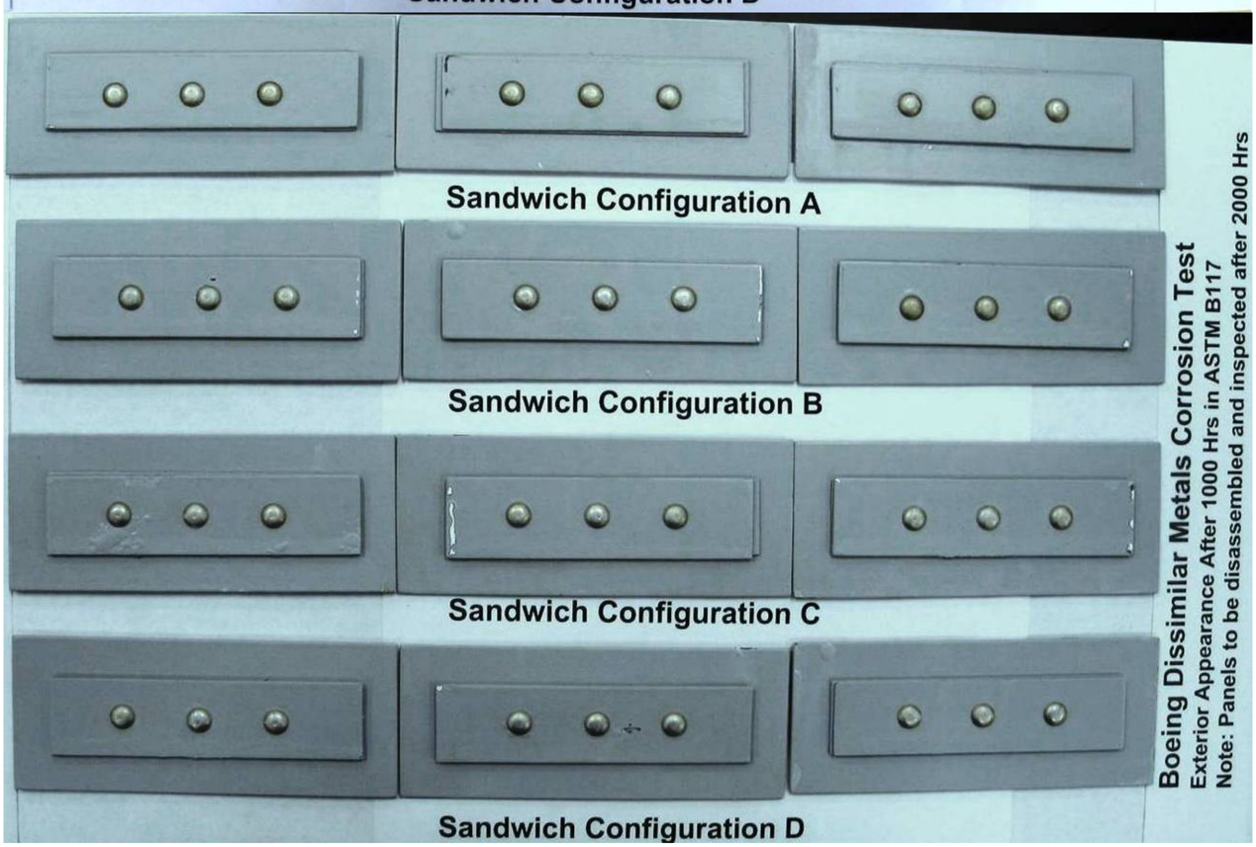
System S: Pantheon PreKote with AquaSur Tech Crosslinker & AST-D45-AMS-MO Sandwich Configuration A&B Aluminum Faying Surfaces at 2000 Hours

System S: Pantheon PreKote with AquaSur Tech Crosslinker & AST-D45-AMS-MO Sandwich Configuration C&D Aluminum Faying Surfaces at 2000 Hours

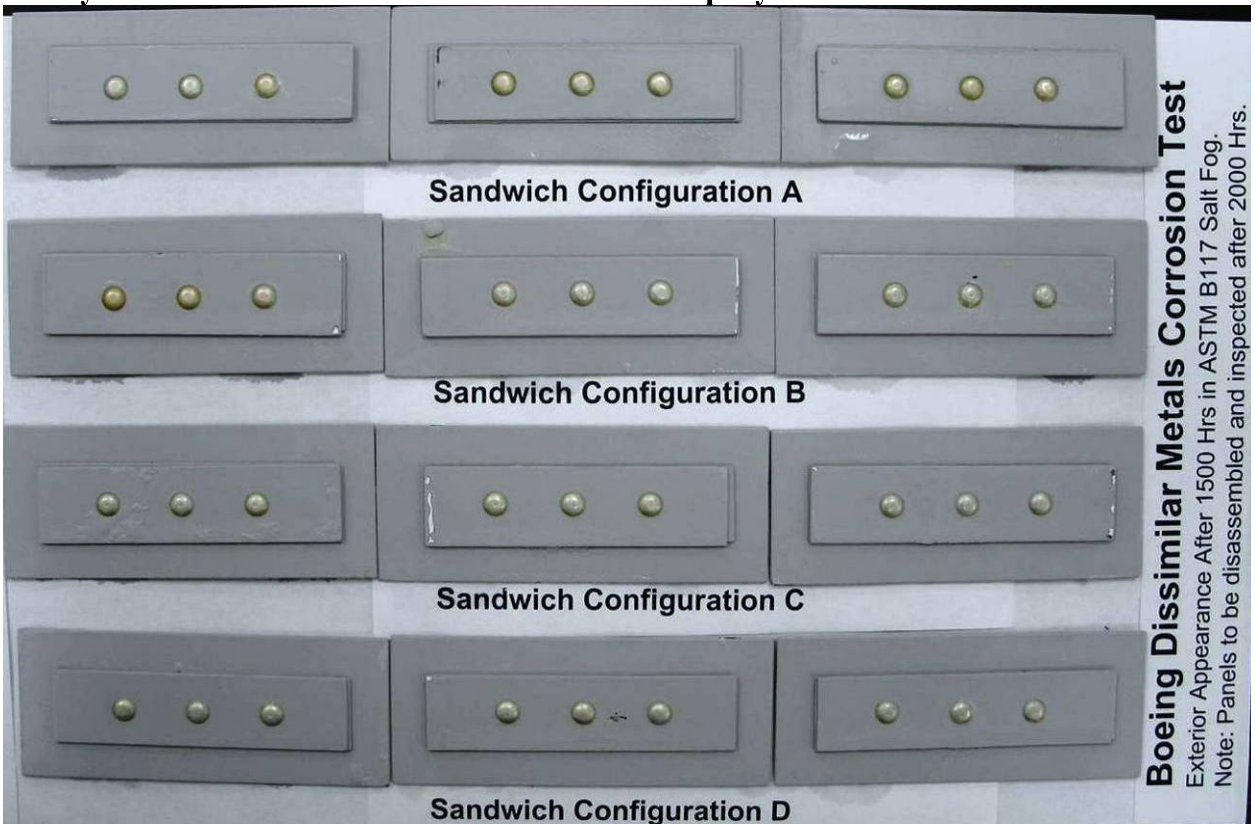


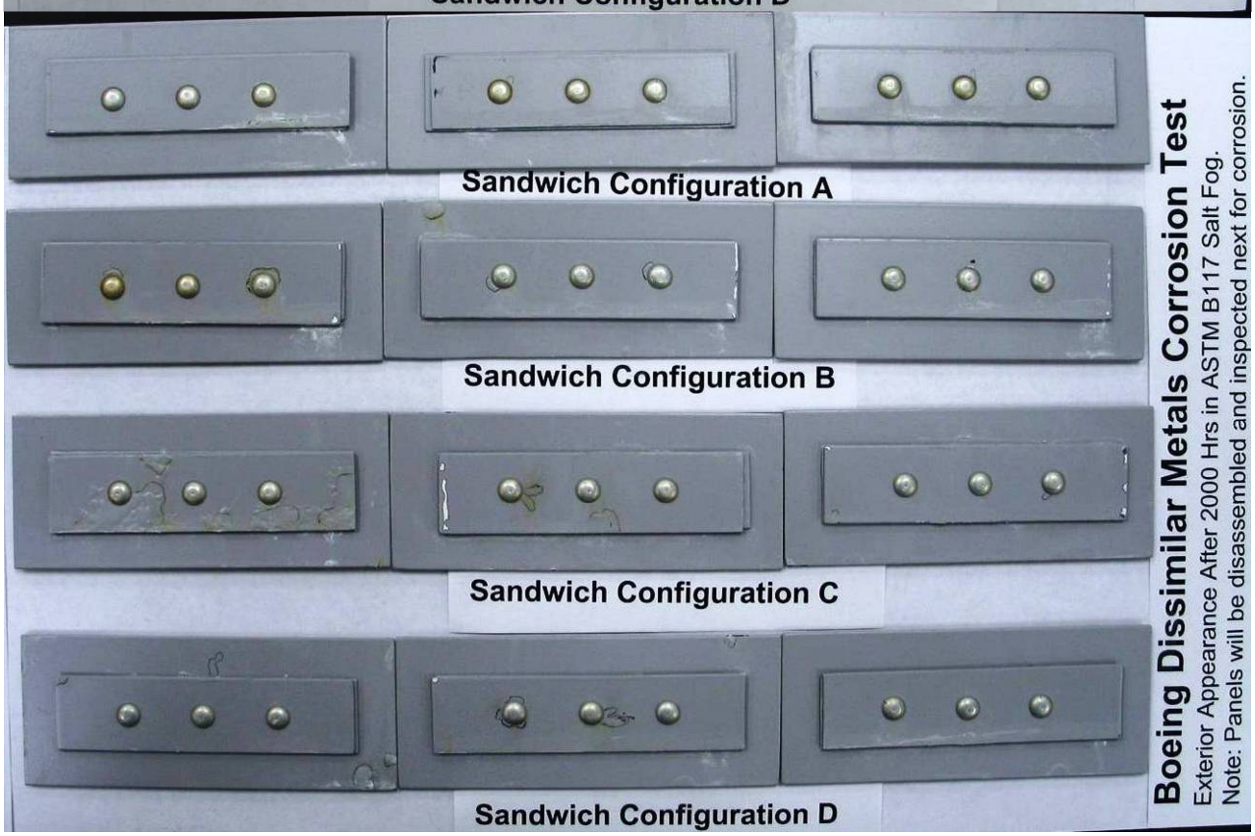
System T: Henkel Alodine 5700 with Akzo Sicopoxy 577-630 at 500 & 1000 Hours





System T: Henkel Alodine 5700 with Akzo Sicopoxy 577-630 at 1500 & 2000 Hours





System T: Henkel Alodine 5700 with Akzo Sicopoxy 577-630 Sandwich Configuration A&B Aluminum Faying Surfaces at 2000 Hours

System T: Henkel Alodine 5700 with Akzo Sicopoxy 577-630 Sandwich Configuration C&D Aluminum Faying Surfaces at 2000 Hours